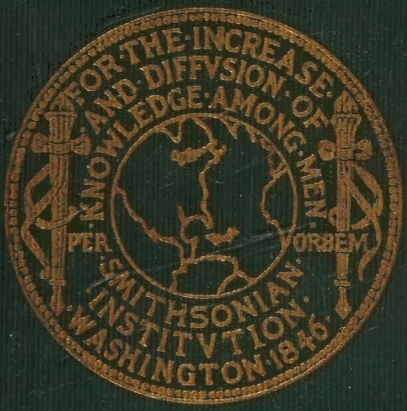
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WASHINGTON 1846

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ANNUAL REPORT OF THE BOARD OF REGENTS OF

THE SMITHSONIAN INSTITUTION

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30

1925

(Publication 2836)

WASHINGTON
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1926

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LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION

SUBMITTING

THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30, 1925

SMITHSONIAN INSTITUTION,
Washington, December 24, 1925.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1925. I have the honor to be,

Very respectfully, your obedient servant,

C. D. WALCOTT,
Secretary.

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ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1925

SUBJECTS

1. Annual report of the secretary, giving an account of the operations and conditions of the Institution for the year ending June 30, 1925, with statistics of exchanges, etc.

2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1925.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1925.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1925.

THE SMITHSONIAN INSTITUTION

June 30, 1925

Presiding officer ex officio.—Calvin Coolidge, President of the United States.

Chancellor.—William Howard Taft, Chief Justice of the United States.

Members of the Institution:

Calvin Coolidge, President of the United States.
Charles G. Dawes, Vice President of the United States.
William Howard Taft, Chief Justice of the United States.
Frank B. Kellogg, Secretary of State.
Andrew W. Mellon, Secretary of the Treasury.
John Wingate Weeks, Secretary of War.
John G. Sargent, Attorney General.
Harry S. New, Postmaster General.
Curtis D. Wilbur, Secretary of the Navy.
Hubert Work, Secretary of the Interior.
William M. Jardine, Secretary of Agriculture.
Herbert Clark Hoover, Secretary of Commerce.
James John Davis, Secretary of Labor.

Regents of the Institution:

William Howard Taft, Chief Justice of the United States, Chancellor.
Charles G. Dawes, Vice President of the United States.
Reed Smoot, Member of the Senate.
George Wharton Pepper, Member of the Senate.
Woodridge N. Ferris, Member of the Senate.
Albert Johnson, Member of the House of Representatives.
R. Walton Moore, Member of the House of Representatives.
Walter H. Newton, Member of the House of Representatives.
George Gray, citizen of Delaware.
Charles F. Choate, jr., citizen of Massachusetts.
Henry White, citizen of Washington, D. C.
Robert S. Brookings, citizen of Missouri.
Irwin B. Laughlin, citizen of Pennsylvania.
Frederic A. Delano, citizen of Washington, D. C.

Executive committee.—George Gray, Henry White, Frederic A. Delano.
Secretary of the Institution.—Charles D. Walcott.
Assistant Secretary.—C. G. Abbot.
Assistant Secretary.—Alexander Wetmore.
Chief clerk.—Harry W. Dorsey.
Accounting and disbursing agent.—N. W. Dorsey.
Editor.—W. P. True.
Librarian.—William L. Corbin.
Appointment clerk.—James G. Traylor.
Property clerk.—J. H. Hill.

NATIONAL MUSEUM

Keeper ex officio.—Charles D. Walcott, Secretary of the Smithsonian Institution.

Assistant Secretary (in charge).—Alexander Wetmore.

Administrative assistant to the Secretary.—W. de C. Ravenel.

Head curators.—Walter Hough, Leonhard Stejneger, George P. Merrill.

Curators.—Paul Bartsch, R. S. Bassler, T. T. Belote, Austin H. Clark, F. W. Clarke, F. V. Coville, W. H. Dall, Walter Hough, L. O. Howard, Aleš Hrdlička, Neil M. Judd, Frederick L. Lewton, George P. Merrill, Gerrit S. Miller, Jr., Carl W. Mitman, Robert Ridgway, Waldo L. Schmitt, Leonhard Stejneger.

Associate curators.—J. M. Aldrich, C. W. Gilmore, W. R. Maxon, Charles E. Resser, Charles W. Richmond, J. N. Rose, Paul C. Standley, David White.

Chief of correspondence and documents.—H. S. Bryant.

Disbursing agent.—N. W. Dorsey.

Superintendent of buildings and labor.—J. S. Goldsmith.

Editor.—Marcus Benjamin.

Photographer.—Arthur J. Olmsted.

Property clerk.—W. A. Knowles.

Engineer.—C. R. Denmark.

Shipper.—L. E. Perry.

NATIONAL GALLERY OF ART

Director.—William H. Holmes.

FREER GALLERY OF ART

Curator.—John Ellerton Lodge.

Associate curator.—Carl Whiting Bishop.

Assistant curator.—Grace Dunham Guest.

Associate.—Katharine Nash Rhoades.

Superintendent.—John Bundy.

BUREAU OF AMERICAN ETHNOLOGY

Chief.—J. Walter Fewkes.

Ethnologists.—John P. Harrington, J. N. B. Hewitt, Francis La Flesche, Truman Michelson, John R. Swanton.

Editor.—Stanley Searles.

Librarian.—Ella Leary.

Illustrator.—De Lancey Gill.

INTERNATIONAL EXCHANGES

Assistant Secretary (in charge).—C. G. Abbot.

Chief clerk.—C. W. Shoemaker.

NATIONAL ZOOLOGICAL PARK

Superintendent.—William M. Mann.

Assistant superintendent.—A. B. Baker.

ASTROPHYSICAL OBSERVATORY

Director.—C. G. Abbot.

Aid.—F. E. Fowle, Jr.

Assistant.—L. B. Aldrich.

REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

Assistant in charge.—Leonard C. Gunnell.

REPORT

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION

CHARLES D. WALCOTT

FOR THE YEAR ENDING JUNE 30, 1925

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith the customary annual report showing the activities and condition of the Smithsonian Institution and the Government bureaus under its administrative charge during the fiscal year ending June 30, 1925. The first 27 pages of the report contain an account of the affairs of the Institution, and in Appendixes 1 to 10 are given more detailed summaries of the operations of the United States National Museum, the National Gallery of Art, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the United States Regional Bureau of the International Catalogue of Scientific Literature, the Smithsonian Library, and of the publications issued under the direction of the Institution.

THE SMITHSONIAN INSTITUTION

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America, "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and therefore constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

The affairs of the Institution are administered by a Board of Regents whose membership consists of "the Vice President, the Chief Justice, three Members of the Senate, and three Members of the House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the city of Washington, and the other four shall be inhabitants of some State, but no two of them of the same State." One of the Regents is elected chancellor by the board; in the past the selection has fallen upon the Vice President or the Chief Justice; and a suitable person is chosen by the Regents as secretary of the Institution, who is also secretary of the Board of Regents and the executive officer directly in charge of the Institution's activities.

The following changes occurred in the personnel of the board during the year: The Hon. Charles G. Dawes, as Vice President, became on March 4, 1925, a Regent of the Institution ex officio. Senator Reed Smoot, of Utah, was appointed a Regent on December 2, 1924, to succeed Senator Henry Cabot Lodge, deceased. Senator George Wharton Pepper, of Pennsylvania, was appointed a member of the board on December 3, 1924, to succeed Senator Medill McCormick, resigned. Senator Woodbridge N. Ferris, of Michigan, was appointed on March 11, 1925, to succeed Senator A. Owsley Stanley, whose term as a Regent expired with his retirement from the Senate.

The roll of Regents at the close of the fiscal year was as follows: William H. Taft, Chief Justice of the United States, chancellor; Charles G. Dawes, Vice President of the United States; members from the Senate, Reed Smoot, George Wharton Pepper, Woodbridge N. Ferris; members from the House of Representatives, Albert Johnson, R. Walton Moore, Walter H. Newton; citizen members, George Gray, Delaware; Charles F. Choate, jr., Massachusetts; Henry White, Washington, D. C.; Robert S. Brookings, Missouri; Irwin B. Laughlin, Pennsylvania; and Frederic A. Delano, Washington, D. C.

GENERAL CONSIDERATIONS

The past year marks a crisis in the affairs of the Institution. For several years past it has grown more and more difficult to stretch the income from its meager endowment sufficiently to cover the steadily increasing costs of even the limited amount of research which can be undertaken and of the administration of the eight growing Government bureaus. The cost of publishing is more than twice that of 10 years ago, which has resulted in materially decreasing the output of Smithsonian publications. The research work of the Institution is now limited practically to the paleontological

work of your secretary and the work on the solar constant of radiation under Doctor Abbot's direction, and both of these investigations are partially supported by private financial aid. The Institution has for several years been undermanned, and the ordinary running expenses are met only by the exercise of rigid economy.

This condition has been recognized for some years, and attempts have been made from time to time to increase the endowment. But during the past year the situation has become acute, and it has been realized that without a marked increase in the Institution's resources it would no longer be able to hold its place among the great research institutions of the present day, the annual income of several of which is greater than the Smithsonian's entire endowment. If allowed to go on under these circumstances, the Smithsonian, America's national scientific establishment, which was the guiding light during the formative period of scientific activity in this country, and which has been the parent of most of the present great scientific bureaus of the Government, would be relegated to second or third rank, and its world-wide reputation as a center of scientific effort in America would rapidly diminish.

With a definite realization of these facts, the administration of the Institution has concentrated during the year upon a direct effort to increase its resources, and by the close of the year several plans were under way and one definite step had been taken toward that end. An agreement was entered into with the William T. De Van Corporation, of New York, to issue a series of popular scientific books, to be known as the Smithsonian Scientific Series, a project similar in general plan to the Chronicles of America series, published by the Yale University Press, which proved so successful under Mr. De Van's direction. In the Smithsonian series it is intended to present in readable form, and profusely illustrated, the activities of the Institution and the bureaus under its direction in many branches of science. The series will consist of 20 volumes, and the following tentative titles of a few will indicate their nature:

Sun-Rays in the Welfare of Man.
Man's Origin and Development.
Gems, Meteorites, and Stones.
North American Indians.
The Study of Our Seas.
Birds and Their Ways.

The preparation of manuscripts was well under way at the close of the year, and it is hoped that before very long the sale of these books will add materially to the Institution's annual income. Two other projects, each holding promise of a large increase of endowment, were under consideration, but final action had not been taken by June 30, and their discussion at this time would be premature.

However, it is believed that as a result of the concerted effort of the administration the outlook for the future is brighter regarding the possibility of increased resources for research and publication.

FINANCES

The permanent investments of the Institution consist of the following:

Deposited in the Treasury of the United States $1,000,000.00

CONSOLIDATED FUND

Miscellaneous securities, etc., either purchased or acquired by gift; cost or value at date acquired 213,386.50

Charles D. and Mary Vaux Walcott research fund, stock (gift); value 11,520.00

The sums invested for each specific fund or securities, etc., acquired by gift are described as follows:

Fund	United States Treasury	Consolidated fund	Walcott research fund	Total
Avery fund	$14,000.00	$32,669.55		$46,669.55
Virginia Purdy Bacon fund		62,272.93		62,272.93
Lucy H. Baird fund		1,528.09		1,528.09
Chamberlain fund		35,000.00		35,000.00
Habel fund	500.00			500.00
Hamilton fund	2,500.00	500.00		3,000.00
Caroline Henry fund		1,223.33		1,223.33
Hodgkins fund, general	116,000.00	37,275.00		153,275.00
Hodgkins fund, specific	100,000.00			100,000.00
Bruce Hughes fund		13,839.90		13,839.90
Morris Loeb fund		5,814.00		5,814.00
Lucy T. and George W. Poore fund	26,670.00	14,183.14		40,853.14
Addison T. Reid fund	11,000.00	6,639.16		17,639.16
Rhees fund	590.00	357.34		947.34
George H. Sanford fund	1,100.00	615.32		1,715.32
Smithson fund	727,640.00	1,468.74		729,108.74
Charles D. and Mary Vaux Walcott research fund			$11,520.00	11,520.00
Total	1,000,000.00	213,386.50	11,520.00	1,224,906.50

The Institution gratefully acknowledges gifts from the following donors:

Dr. William L. Abbott, for botanical expedition to Haiti.

The Buffalo Society of Natural Sciences, for expedition to southern Asia, Java, Australia, and Africa (Hrdlička).

National Academy of Sciences, for researches in paleontology.

Research Corporation, for research work.

Dr. Charles W. Richmond and Dr. William Schaus, for collecting expedition in China.

Mr. John A. Roebling, for solar researches, etc.

Mr. B. H. Swales, for purchase of specimens.

The Institution has also received contributions from the following friends for the funds as listed below:

General endowment fund: Miss Anne C. Hanson, Mr. R. B. Miller, Mr. R. S. Poor, Prof. M. V. Walker, and Mr. Hans Wilkens.

Endowment campaign expense fund: Mr. Milton E. Ailes, Mr. Charles F. Choate, jr., Mr. Charles C. Glover, jr., Mr. Irwin B. Laughlin, and the Hon. William Howard Taft.

Smithsonian Scientific Series: Mrs. Martha W. Bacon, Mr. Edward S. Harkness, Mr. Clarence H. Mackay, the Radio Corporation of America, and Mr. Samuel Rea.

Freer Gallery of Art.—The invested funds of the Freer bequest are classified as follows:

Court and grounds fund	$278,825.50
Court and grounds, maintenance fund	69,683.75
Curator's fund	278,825.50
Residuary legacy	2,676,232.75
Sinking fund	222,658.75
Total	3,526,226.25

The practice of depositing on time, in local trust companies and banks, such revenues as may be spared temporarily has been continued during the past year, and interest on these deposits has amounted to $1,610.15. The income during the year for current expenses, consisting of interest on permanent investments and other miscellaneous sources, amounted to $62,507.06; revenues and principal of funds for specific purposes, except the Freer bequest, amounted to $148,252.88; revenues on account of Freer bequest amounted to $231,073.64—aggregating $441,833.58.

The disbursements, described more fully in the annual report of the executive committee, were classed as follows: General objects of the Institution, $59,921.20; for specific purposes (except the Freer bequest), $128,334.53; and expenditures pertaining to the Charles L. Freer bequest, $184,190.26. The balance on hand on June 30, 1925, was $171,952.75.

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1925:

International exchanges		$49,550.00
American ethnology		57,160.00
International Catalogue of Scientific Literature		8,861.66
Astrophysical Observatory		21,580.00
Additional assistant secretary		6,000.00
Additional fire protection		8,500.00
National Museum:		
Furniture and fixtures	$21,800.00	
Heating and lighting	77,560.00	
Preservation of collections	434,482.00	
Building repairs	11,000.00	
Books	2,000.00	
Postage	450.00	
		547,292.00
National Gallery of Art		20,158.00
National Zoological Park		151,487.00
Printing and binding		90,000.00
Total		960,588.66

RESEARCHES AND EXPLORATIONS

An important part of the Institution's work in increasing scientific knowledge is the exploration of regions imperfectly known to science. Although the limited funds of the Institution sharply restrict the number of expeditions which it is able to put in the field, nevertheless it is often found mutually advantageous to cooperate with other agencies in field work, and the Institution thus has an interest in a considerable number of expeditions each year. Many of them are conducted under the direct supervision of the heads of several of the bureaus under the Institution, and accounts of these will be found in the reports appended hereto on the National Museum, the Bureau of American Ethnology, and the Astrophysical Observatory. A few of the expeditions will here be described briefly, in order to give an indication of the nature of the work undertaken.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES

During the field season of 1924, your secretary carried on his usual geological work in the Canadian Rocky Mountains, with the intention of completing the reconnaissance begun some years ago of the pre-Devonian formations north of the Bow Valley. The weather was unusually unfavorable, and on 42 days out of the season it was very difficult and sometimes impossible to carry on the field work. The chief problem attacked was the determination of the proper classification of the great Lyell limestones. In order to solve this it was necessary to find fossils in them, and during the past six seasons all such attempts were unsuccessful.

A section was measured from Fossil Mountain, situated northeast of Lake Louise station on the Canadian Pacific Railway, eastward into Oyster Mountain, the main north and south ridge of which was found to be formed of the Lyell limestones. Two glacial cirques, named Cotton Grass and Tilted Mountain, cut deeply into this ridge, and in these the base of the Lyell formation was uncovered, as well as the shales and oolitic limestones of the underlying Bosworth formation. The brook running out of the glacial lake in the bottom of the southern cirque was followed over the ledges of Lyell limestone westward to Tilted Mountain Falls, where it drops into the canyon valley of upper Baker Creek. Everywhere the hard, unfossiliferous, light gray limestone was encountered, except near the edge of the cliffs above and east of the falls, where long narrow strips covered with grass and trees occur between the north and south ledges. An approach was made from the southern bank of the brook, and on a rounded, glaciated ridge of the gray magnesian Lyell limestone there was found, interbedded in the Lyell, an outcrop of thin layers of a bluish-gray limestone which contained frag-

ments of Upper Cambrian trilobites. The next day these layers were traced back to the brook, and a little lower in the section we found two bands of shale and bluish-gray limestone which contained fossils. The lower of the two contained many fragments of trilobites, which were later identified as closely related to Upper Cambrian Franconia trilobites from Wisconsin, and the upper band contained fossils of the same type as the fauna of the St. Lawrence member of the Trempeauleau formation of Wisconsin. Thus after a search occupying a portion or several field seasons, fossils were found which definitely located the Lyell limestones as of Upper Cambrian age.

After the Lyell problem was definitely settled, further collections of fossils were made in the Ozarkian upper Mons limestones of Fossil Mountain, and later in the Mons formations of Wild Flower Canyon, which heads on Johnston Creek Pass.

During the past eight seasons considerable progress has been made in the understanding of the pre-Devonian geological formations and their faunas in the Canadian Rocky Mountains, but much remains to be done, particularly in the region between the Canadian Pacific Railway and the Arctic Ocean.

ZOOLOGICAL EXPLORATIONS IN WESTERN CHINA

In my last report mention was made of the tragic ending of the Institution's collecting expedition in China conducted under the auspices of Dr. W. L. Abbott. Mr. Charles M. Hoy, in charge of the work, following a series of misfortunes, was stricken with a severe case of appendicitis, and died shortly after. In order that Hoy's work might be continued, his collecting outfit was transferred to the Rev. David C. Graham, who for a number of years has collected zoological material in the vicinity of Suifu for the National Museum. In 1923 he had carried out very successful collecting operations in the region about Tatsienlu, to the northwest of Suifu, and in May, 1924, plans were completed for an expedition to Songpan, in the northern part of the Province of Szechwan, using Hoy's outfit.

The distance from Suifu to Songpan was about 400 miles, and in order to keep down expenses Mr. Graham covered most of this distance on foot. His party, including carriers, skinners, and other helpers, reached Songpan on July 14, after a strenuous journey of 22 days. In September Mr. Graham wrote as follows:

> The Songpan trip has been taken, and we are safely at Suifu with 50 boxes of specimens, most of which are about ready to be mailed by parcel post.
>
> This has been a harder and rougher trip than the one of Tatsienlu or any other previous trip. It is much harder to secure food and other necessities around Songpan than at Tatsienlu. There were times when we could pur-

chase no fruit, vegetables, eggs, or meat. At Songpan it was impossible to go west or north, where large mammals were found in abundance, so that the only place we could go was east to the Yellow Dragon Gorge. Even there we had to have an escort of six Chinese soldiers and had of course to pay all their expenses. * * *

The reason we could not go north of Songpan or west of that place was that the Bolotsi aborigines are so savage and so inclined to murder and brigandage that the Chinese can not control them and are afraid of them, and the officials could not protect us in those regions. Just before we returned from Songpan the Bolotsis attacked a company of Chinese soldiers, killed several of their number, stole several rifles, and drove the scared and defeated soldiers back to their barracks. I have not heard that the Chinese have dared to go into the Bolotsi country with a punitive expedition.

The catch of mammals is not large. We are very sorry about this. It is due primarily to the fact that the mammal-catching districts around Songpan were closed to us. Yellow Dragon Gorge was a fine place for birds and insects, but a great festival had just been held there, in which aborigine and Chinese hunters from all directions had joined in the chase, and woodcutters were busy in the woods cutting timber for the new temples that are being constructed. The mammals had been scared away.

Mr. Graham also sent native collectors out to work in other regions, and regarding their work he says:

This year's catch is bigger than that of last year. There are 50 boxes of specimens on hand, and I expect to send them off by parcel post as early as possible. Besides the 50 boxes just mentioned, there is the entire catch of the netter Ho for at least three months, who has been collecting about Beh Luh Din, Chengtu, and Kuanshien during the summer, and specimens now being secured by two collectors on Mount Omei, one at Shin Kai Si and one on the higher altitudes.

The collections resulting from the season's work include about 5,000 insects, notably two-winged flies, butterflies, and moths; 558 birds, of which at least a dozen proved to be new to the Museum collections; about 250 mollusks; and a smaller number of mammals, fishes, reptiles and batrachians, earthworms, and plants.

BOTANICAL EXPLORATION IN PANAMA AND COSTA RICA

Mr. Paul C. Standley, associate curator of the division of plants, United States National Museum, engaged in botanical exploration during the latter part of 1923 and the first four months of 1924 in Panama and Costa Rica. The work in Panama was carried on with the cooperation of the government of the Panama Canal, and had for its purpose the collection of specimens and data for a report on the plant life of the Canal Zone which will be published later. Regarding the exploration in Panama, Mr. Standley writes:

Part of November, December, and most of January were spent in botanical exploration in and near the Zone. Nearly all parts of this area were visited, and 7,000 numbers of plants were obtained, represented by about twice as many specimens. These collections are now being studied and have been found to contain a number of species new to science, besides many not collected previously in the area.

The vegetation of the Zone is typical of that existing in Central America at low elevations, but it is here possible to study in close proximity the floras of the Atlantic and Pacific slopes, these floras being sharply differentiated in Central America because of differences in the climates of the two watersheds. The Pacific slope has well defined wet and dry seasons; on the Atlantic slope there is usually plentiful moisture throughout the year.

Although the original vegetation of the Isthmus of Panama has been greatly modified in many places because of long occupation by man, and especially because of operations incident to the construction and management of the canal, there remain near the canal extensive areas of virgin forest whose animal and plant life is of great interest. Advantage has been taken of this fact to establish recently a station for tropical scientific research on Barro Colorado Island in Gatun Lake, the island having been set aside for the purpose by the governor of the canal. Upon this island, largely as a result of the energy and enthusiasm of Mr. James Zetek, there has been constructed this year a laboratory building with accommodations for students, and trails have been cut to make the virgin forest, which covers several hundred acres, available for study.

From Panama, Mr. Standley proceeded to Costa Rica, where he spent two and one-half months in botanical exploration and collecting. Costa Rica is, from a botanical standpoint, probably the richest part of the North American continent, and in the highland region, where a temperate rather than tropical climate prevails, the luxuriance and variety of the vegetation is extraordinary. Of the Costa Rica work, Mr. Standley reports:

The collection consists of 8,000 numbers of plants, many of which will doubtless prove to be new. Special attention was given to the orchids, of which about 1,500 numbers were obtained. These are now being studied by Mr. Oakes Ames, through whose interest the work in Costa Rica was undertaken. Of orchids Costa Rica possesses probably a larger number of species than any other portion of the American tropics of equal extent. Over 1,000 species have been reported from this small Republic, and it is certain that many more await discovery. While most Costa Rican orchids, like those of other countries, have inconspicuous flowers, some, such as the Cattleyas, are of unsurpassed beauty.

Visits were made to the Volcano of Poas, celebrated for its great crater, which contains a lake that erupts frequently; to the Volcano of Turrialba, whose forests are noted for their wealth of ferns; and to many other rich localities in the central highlands.

A short visit to the comparatively arid Pacific coast proved that the flora of this part of Costa Rica is relatively meager and uninteresting. Several visits were made to the wet lowland forests of the Atlantic watershed, where the vegetation is even more luxuriant than in the mountains and the species are almost equally numerous. Little is known of the plants of the Atlantic lowlands of Central America, although it is probably that no other region will better reward exploration.

ARCHEOLOGICAL EXPEDITION TO CHINA

An expedition to China under the joint auspices of the Freer Gallery of Art and the Museum of Fine Arts, Boston, and directed

by Mr. Carl Whiting Bishop, associate curator of the Freer Gallery, conducted successful archeological investigations at I Chou, Province of Chihli, and at various localities in the Province of Shensi. To the southwest of I Chou, which is built upon the ruins of an ancient city, Mr. Bishop discovered parts of old earthen walls of considerable size, and to the east of the city were found groups of large mounds rising from the plain. These were examined, and many fragments of pottery and tile collected on the surface of the mounds. A survey of the locality was made by airplane, in order to determine the extent and plan of the ancient site.

Although the work of this expedition commenced during the previous fiscal year, it was continued into the present year; and, as no detailed account was given in my last report, I will quote a few paragraphs from the report of the curator of the Freer Gallery upon the work at Shensi:

In Shensi the members of the field staff visited the Western Han (206 B. C.—A. D. 25) capital of Ch'ang-an, securing sufficient data while there to make a fair reconstruction of the ancient city. In the same Province they inspected also two large mounds of the usual truncated pyramidal form, ascribed to early Han emperors; the supposed tomb of the Emperor Ch'in Shih Huang-ti (221–210 B.C.), and the tombs of the famous Emperor Han Wu Ti (140–87 B. C.), and his General Ho Ch'ü-ping. The tomb of Han Wu Ti is an unusually large one, measuring 278 yards at its base, and presents opportunities of great archeological interest, as does also that of General Ho Ch'ü-ping, where Mr. Bishop saw not only the well-known stone figure of a horse trampling on a recumbent warrior but examined also several other partially exposed stone sculptures of the early Han period. Photographs and scale plans of several of the tombs and temples in this vicinity were made.

The first actual excavation work conducted by the expedition was begun in the spring of this year at Yü-ho Chên, about 17 miles west of Hsin-yang Chou, in the Province of Honan. This specific undertaking has an added significance archeologically, in that it is the first work of the kind to be conducted in China by any foreign Government in cooperation with the Chinese authorities. At Yü-ho Chên two tombs of the Han dynasty (206 B. C.—A. D. 221) were excavated; the work revealed interesting data on ancient tomb construction, and brought to light Chinese cultural objects dating from prehistoric times to the Han period. Specimens in metal, stone, and pottery were found in the tombs; chariot fittings, mirrors, and arrow points of bronze; one or two gold rings; cast-iron implements; a stone ax, and parts of stone doors and lintels; a jade chisel; slate arrow-heads, and a number of pieces of ancient pottery—some intact, some fragmentary—among them a kind of glazed pottery which, if it be of Han production, is a type hitherto scarcely known to us.

In August the Yü-ho Chên finds were exhibited for one day, under Mr. Bishop's direction, at the Historical Museum in Peking; between 5,000 and 6,000 visitors attended the exhibit.

In the early autumn Mr. Bishop, together with Doctor Barbour, professor of geology at Peking University, and Doctor Tegengren, a Swedish mining geologist, examined a mound in Peitaiho, on the Gulf of Chihli, which dis-

closes evidences of what Mr. Bishop believes to be a Han dynasty naval base or fortress, one of three which are said to have been built at that time, and of which two only have been located.

MARSH-DARIEN EXPEDITION

An expedition under the auspices of Mr. R. O. Marsh explored during a part of 1924 the little-known Isthmus of Darien, in Panama. A number of men representing several institutions and various branches of science accompanied the expedition at the invitation of Mr. Marsh, the Smithsonian Institution being represented by Mr. John L. Baer, who was particularly interested in the anthropological phase of the work. This expedition, like that of Mr. Hoy mentioned in last year's report, had a tragic ending, so far as the Institution was concerned, for while the party was proceeding up the Chucunaque River Mr. Baer was taken suddenly ill, and, although hurriedly transported to the coast, he died within a few days.

A brief report of the work of the expedition, written by the head curator of anthropology of the National Museum, reads in part as follows:

The route followed was from Balboa to San Miguel Bay, through Darien Harbor, and up the Tuyra River to the village of Real. There a change was made to smaller boats and the Rio Chucunaque ascended to Yavisa, near which a permanent camp was established. A visit was made to the Choco Indians, who occupy the middle river valleys above tidewater, and to the Cuna, who live in the higher river valleys and mountain district. The Choco have a local government, live in large, well-built community houses, and subsist on rice, bananas, plantains, corn, and yucca. They are expert fishermen, diving into deep pools and catching certain kinds of rock fish in their hands. Their religion is a form of primitive belief in the influence of good and bad spirits. Mr. Marsh observes that they are a happy, careless, childlike people, friendly if well treated, very Polynesian-like, wearing breech-cloths, but decorated with beads, silver earrings, and wrist bands, and wreaths of gay flowers.

The Cuna have a higher culture than the Choco, are monogamous, have hereditary chiefs, families have separate houses, and large houses are used for tribal meetings and ceremonies. They raise long-staple tree cotton, dye and weave cotton into cloth and hammocks, grow corn, plantains, bananas, yucca, coffee, chocolate, and sugar cane. They are adepts with the bow and arrow and blowgun.

The party proceeded up the Chucunaque River with great difficulty, owing to barriers of drift logs, at last reaching the Cunas Bravos, who were regarded as hostile. The Cunas Bravos are agriculturalists and exhibit a lower degree of culture than the Cunas of the lower river. The chief of the Cunas Bravos spoke good English, having as a young man shipped at Colon on an English vessel, and in 12 years had sailed over half the world. It was at this point that John L. Baer became ill.

Activities were next transferred to the San Blas Indians, who inhabit a long stretch of the north coast of Panama. These Indians, who number approximately 40,000, have always kept aloof from the white man, realizing

that contact with other races would work their undoing. Amicable relations were established with them and many interesting specimens of their arts and industries were collected for the National Museum. The San Blas Indians have an advanced social organization, with a ruler who could perhaps be properly classed as a king. Through the San Blas, Mr. Marsh came in contact with hundreds of "white Indians" whose presence in Panama has been known for a long time but who have not been examined by scientific observers. Individuals brought by Mr. Marsh to the United States have been carefully examined and tentatively stated, before field studies go more fully into the matter, to present a form of albinism.

ADDITIONAL ASSISTANT SECRETARY

For several years there has been recognized the need of an additional assistant secretary to relieve the pressure on the Institution of administration of the eight Government bureaus, several of which have developed rapidly in recent years. This need was laid before Congress, and in the last appropriation bill provision was made for the new position. After a thorough study of the qualifications needed for the position, Dr. Alexander Wetmore was appointed on April 1, 1925, as Assistant Secretary of the Smithsonian Institution, with general supervision of the National Museum, the National Gallery of Art, and the National Zoological Park.

Doctor Wetmore graduated from Kansas State University in 1912, having specialized in biology. He carried on post-graduate studies in biology at George Washington University, receiving the degree of M. S. in 1916 and Ph. D. in 1920. Since 1910 he has served in the Biological Survey, Department of Agriculture, first as agent, then as assistant biologist, and finally as biologist, with official station at Washington, D. C.

During Doctor Wetmore's connection with the Biological Survey he conducted numerous investigations dealing with birds and mammals, and in 1923 directed the U. S. S. *Tanager* expedition which engaged in general scientific exploration of islands in the Pacific.

On November 18, 1924, he was appointed superintendent of the National Zoological Park, where he exhibited unusual administrative ability, and on April 1, 1925, he was installed in his new position.

SMITHSONIAN RADIO TALKS

In my last report there was described the beginning of a series of radio talks by the Smithsonian Institution in cooperation with station WRC of the Radio Corporation of America, as an addition to the Institution's established methods of the diffusion of knowledge. The entire matter was placed in charge of Mr. Austin H. Clark, curator of echinoderms in the National Museum, and under his able and enthusiastic direction the series of talks was a distinct success, as attested by calls and letters from many listeners.

On October 2, 1924, the series of talks was begun again, with increased scope, and between that date and May 14, 1925, twenty-eight 15-minute talks were presented to the radio audience under the auspices of the Smithsonian Institution through station WRC, four of these having been broadcast jointly with stations WJY and WJZ of New York City, thus considerably extending the audience. Ten of these talks were given by members of the staff of the Institution, the other 18 having been given by scientists representing other establishments selected by and presented under the auspices of the Smithsonian. A list of the talks given during the year follows:

SMITHSONIAN RADIO TALKS (1924–1925)

October 2, 1924. Life in the Sea. Mr. Austin H. Clark.

October 16, 1924. Wonders of the Deep Sea. Capt. Frederick B. Bassett, hydrographer of the Navy.

October 22, 1924. Curious Plants. Dr. F. V. Coville.

November 8, 1924. What the Ocean Means to Us. Lieut. Commander George E. Brandt, aid to hydrographer of the Navy.

November 13, 1924. Indian Cliff Dwellings. Dr. J. Walter Fewkes.

November 20, 1924. Living Lamps. Mr. Austin H. Clark.

December 11, 1924. The Ocean Bottom. Dr. George W. Littlehales, hydrographic engineer, Navy Department.

December 25, 1924. What Standards Mean to Us. Dr. Fay C. Brown, assistant director, Bureau of Standards.

December 30, 1924. How Trees Grow. Dr. D. T. MacDougall, director, Desert Botanical Laboratory of the Carnegie Institution, Tucson, Ariz.

December 31, 1924. Why the Earth is a Magnet. Prof. W. F. G. Swann, Yale University.

January 3, 1925. Tree Rings and Climate. Dr. A. E. Douglass, University of Arizona.

January 8, 1925. The Sun and the Weather. Dr. C. G. Abbot.

January 22, 1925. The Weather. Prof. W. J. Humphreys, United States Weather Bureau.

January 29, 1925. Mysteries of Bird Migration. Dr. F. C. Lincoln, United States Biological Survey.

February 5, 1925. The Ocean's Food Resources. Mr. Lewis Radcliffe, Deputy Commissioner of Fisheries.

February 12, 1925. What Other Peoples Eat. Mr. Austin H. Clark.

February 19, 1925. What the Earth is Made Of. Dr. Henry S. Washington, Carnegie Institution.

February 26, 1925. Habits of Ants. Dr. William M. Mann, Bureau of Entomology.

March 12, 1925. Fish as Food. Mr. Lewis Radcliffe, Deputy Commissioner of Fisheries.

March 19, 1925. How Some Wasps Live. Mr. S. A. Rohwer, Bureau of Entomology.

March 26, 1925. The Work of the Coast and Geodetic Survey in Saving Life and Property at Sea. Col. E. Lester Jones, Director Coast and Geodetic Survey.

April 2, 1925. Mosquitoes and Other Bloodsucking Flies. Mr. Raymond C. Shannon, Bureau of Entomology.

April 9, 1925. Lizards and Their Kin. Miss Doris M. Cochran.

April 16, 1925. Fighting Plant Diseases by Breeding New Plants. Dr. W. A. Taylor, Chief, Bureau of Plant Industry.

April 23, 1925. Our Fisheries. Hon. Henry O'Malley, Commissioner of Fisheries.

April 30, 1925. The Geodetic Work of the United States Coast and Geodetic Survey. Col. E. Lester Jones, Director Coast and Geodetic Survey.

May 7, 1925. Chiggers, Ticks, and Fleas. Dr. H. E. Ewing, Bureau of Entomology.

May 14, 1925. Butterflies. Mr. Austin H. Clark.

This Smithsonian radio series has proved to be an excellent means of disseminating authentic scientific information, and Mr. Clark had already begun at the close of the fiscal year to arrange the program for the coming year. It is intended to increase not only the scope of the talks, but also the audience to be reached by exchanging material with Westinghouse station WBZ, of New England.

Plans were under way also, near the close of the year, for a distinct series of radio talks on the National Zoological Park, to be presented by the superintendent of the park and others who have a special knowledge of certain groups of animals shown in the park. It is expected to begin this series in October, 1925.

PUBLICATIONS

A total of 155 volumes and pamphlets were issued during the year by the Institution and the Government bureaus under its administration. Of these, 171,865 copies were distributed, including 262 volumes and separates of the Smithsonian Contributions to Knowledge, 24,008 of the Smithsonian Miscellaneous Collections, 26,825 volumes and separates of the Smithsonian Annual Reports, 6,102 special Smithsonian publications, 104,596 volumes and separates of the various series of National Museum publications, 7,354 publications of the Bureau of American Ethnology, 68 volumes of the annals of the Astrophysical Observatory, 44 reports on the Harriman Alaska expedition, and 1,057 reports of the American Historical Association.

The publications of the Institution constitute its principal means of carrying out one of its main purposes, "the diffusion of knowledge among men." With the 11 distinct series now issued, a very wide field of readers is reached, as in addition to the technical papers, intended for use by scientists and students, a semipopular account of progress in all branches of science is presented to the general reader in the appendixes to the annual reports of the Institution. As explained in last year's report, these reports have since the war been issued over two years late. Last year, however, funds were provided to enable the Institution to bring them up to date

by issuing two reports in one year, and this has now been accomplished, the report for 1923 having been received from the printer in June, 1925, and the 1924 report promised for delivery in October, 1925. This is probably as nearly on time as the reports can be issued, owing to their complicated nature, which involves the assembling of material from foreign as well as American sources and the submitting of proof to some 30 authors in all parts of the world.

Allotments for printing.—The congressional allotments for the printing of the Smithsonian report to Congress and the various publications of the Government bureaus under the administration of the Institution were practically used up at the close of the year. The appropriation for the coming year ending June 30, 1926, totals $90,000, allotted as follows:

Annual Report to the Congress of the Board of Regents of the Smithsonian Institution	$12,500
National Museum	42,500
Bureau of American Ethnology	25,600
National Gallery of Art	1,200
International Exchanges	300
International Catalogue of Scientific Literature	100
National Zoological Park	300
Astrophysical Observatory	500
Annual Report of the American Historical Association	7,000

Committee on printing and publication.—The Smithsonian advisory committee on printing and publication considers and makes recommendations concerning all manuscripts offered for publication. It also assists in determining the publication policy of the Institution and endeavors to insure the most efficient administration of all funds for printing and binding. During the year five meetings were held and 75 manuscripts acted upon. A vacancy was created in the personnel of the committee by the death of Mr. N. Hollister, superintendent of the National Zoological Park. Dr. Alexander Wetmore, who succeeded him as superintendent of the park, also took his place on the committee. Upon Doctor Wetmore's appointment as an assistant secretary of the Institution, he in turn was succeeded on the committee by Dr. William M. Mann, the present superintendent of the park. The membership of the committee is as follows: Dr. Leonhard Stejneger (chairman), Dr. George P. Merrill, Dr. J. Walter Fewkes, Dr. William M. Mann, Dr. Marcus Benjamin, Mr. Stanley Searles, and Mr. W. P. True, secretary.

LIBRARY

During the year the most important change in the staff of the Smithsonian library was the appointment of Mr. William L. Corbin as librarian. Mr. N. P. Scudder, assistant librarian in charge of the National Museum library for the past 38 years, died May 19, 1925.

The accessions to the libraries, exclusive of those to the library of the Bureau of American Ethnology, which is reported on by the chief of the bureau, totaled 12,537. The most outstanding gift of the year was the entomological library of the late Col. Thomas L. Casey, numbering about 4,500 volumes and pamphlets, chiefly on coleoptera, which will be deposited in the section of insects of the National Museum.

The loans totaled 10,657. Special effort was made to supply requests for missing volumes or parts of volumes, and 2,009 were obtained. There were sent to the Library of Congress 7,287 publications to be added to the Smithsonian deposit and 7,408 documents of foreign governments for the document division. Seven thousand one hundred and thirty-two volumes and pamphlets were catalogued and much general work was done on the collections, including a detailed investigation by the librarian of the needs of the library.

NATIONAL MUSEUM

By the action of the Congress in providing for the appointment of an additional assistant secretary of the Smithsonian Institution to have general supervision of the National Museum and certain other Government bureaus under administrative charge of the Institution, Dr. Alexander Wetmore was appointed to that office on April 1, 1925. The application of the reclassification act resulted in the adoption of a more just salary scale for the scientific staff, and for the first time in many years every position in the Museum personnel was filled, the salaries previously available for certain positions having been too small to attract men properly equipped to hold them. The increase of $52,396 in the Museum appropriations over last year was sufficient to cover the larger salaries, but does not allow for proper advancement for efficient service, as provided in the reclassification act. Additional funds are urgently needed for this purpose and also for the normal expansion of the Museum, including the purchase of specimens, and for use in minor explorations.

The Museum contributed during the past winter seven speakers to the series of Smithsonian radio talks, organized last year under the direction of Mr. Austin H. Clark. This new field for the dissemination of knowledge offers great possibilities.

The Loeb collection of chemical types has made splendid progress under the direction of Mr. O. E. Roberts, jr., curator, 616 new specimens having been added to the collection during the year.

The Museum received during the year 363,490 specimens, a slight increase over last year's accessions, and 1,232 additional lots of material were received for examination and report. A total of 23,244 duplicate specimens were distributed as gifts to educational institu-

tions or exchanged for specimens needed to complete collections in the Museum, and 33,966 specimens were distributed as loans to specialists and students for study and identification.

The accessions to the Museum collections in all its departments are described in detail in the report of the assistant secretary, Appendix 1, and only a few of the outstanding gifts will be mentioned here. In the department of anthropology, the ethnological collections were enriched by the addition of a unique series of objects illustrating the material culture of the Indians of eastern Panama, resulting from the Marsh-Darien expedition, and by a collection of California Indian baskets bequeathed by the late Miss Ella F. Hubby, of Pasadena. In physical anthropology, a number of casts of the remains of early man were received, including several of the famous Trinil man of Java, *Pithecanthropus erectus*, from Dr. Eugene Dubois, and also much valuable skeletal material. The department profited especially through explorations conducted by the Bureau of American Ethnology, and by the National Geographic Society under the direction of Mr. Neil M. Judd, which resulted in valuable additions to the collections.

The most notable gift to the department of biology was the collection of Coleoptera and mollusks bequeathed to the Museum by the late Col. Thomas Lincoln Casey. The beetles alone in this collection are estimated at 90,000 specimens, representing 16,000 species. A wonderful store of rich material also has been added to the department in the large collections presented by the National Geographic Society as the result of expeditions in China by Dr. J. F. Rock and Mr. F. R. Wulsin, which include 4,500 specimens of vertebrates and 68,000 plants. Additional collections from China have also been received from the Rev. D. C. Graham and Mr. A. de C. Sowerby.

In the department of geology, the paleontological collections have been the chief beneficiaries, having received the results of your secretary's field work for the past four years, as well as collections made by Doctor Bassler, Doctor Resser, and Doctor Ulrich. The other divisions have all received valuable additions, including a number of interesting minerals contributed by Col. W. A. Roebling, and a crystal of the new mineral, afwillite, donated by Mr. Alpheus F. Williams. One of the most interesting exhibits is a crystal ball of unusual size and perfection, weighing 110 pounds and measuring 13¼ inches in diameter, shown through the interest of Mr. Worcester R. Warner and the courtesy of the Fukushima Co. (Inc.), New York. This ball is said to be the largest of its kind in the world and has attracted much attention from visitors.

In the division of mechanical and mineral technology there was a slight falling off in the number of accessions received, principally

due to a lack of exhibition and storage space. Interesting additions were made, however, in the transportation section, including one early type of automobile, a Knox car, made in 1901, presented by Mrs. Lansing Van Auken, of Watervliet, N. Y.

The division of textiles, under which are administered also wood technology, organic chemistry, foods, and medicine, received over 8,800 objects during the year, more than twice the number received last year. These included several series of industrial specimens illustrating the manufacture of rubber, sealing wax, and the preparation and dyeing of furs; samples of silk, cotton, and wool fabrics for the textile collections; specimens of woods used in the furniture industry; and, for the public health exhibit, models and posters showing advances in sanitary science.

The exhibits of the division of graphic arts have been greatly improved during the past year by the addition of valuable new material and the rearrangement of the collections. Fourteen special exhibitions of prints in various media, mainly the work of contemporary artists, were held and the two traveling exhibits prepared by the division were widely circulated among the art museums and graphic art organizations of the eastern part of the country.

Among the objects of special interest added to the historical collections were a presentation sword, flags, uniforms, medals, and badges of the late Lieut. Gen. Nelson A. Miles; additional numismatic material, including 800 publications on numismatics transferred from the Treasury Department; and four portraits added to the portrait collection.

The Museum participated in a number of field expeditions, described in the report on the Museum, appended hereto, which have resulted in the addition of much valuable material in all of the departments of the Museum. The auditorium was in frequent demand by scientific and other societies and organizations for meetings and lectures. Visitors to the Natural History Building totaled 557,016; to the Arts and Industries Building, 304,858; to the Aircraft Building, 52,787; and to the Smithsonian Building, 107,342, making in all a total of 1,022,003. This is the first time in the history of the Museum that the year's attendance has exceeded 1,000,000 individuals. Five volumes and 70 separates were published as the result of Museum activities during the year, and 104,596 copies of Museum publications were distributed.

NATIONAL GALLERY OF ART

During the past year additions to the gallery collections were less than in previous years owing to the lack of exhibition space. The art works awaiting approval at the present time do not ex-

ceed $100,000 in estimated value, while, with a suitable art building, it is thought that gifts and bequests to the value of a million dollars or more would be received annually.

Work has been continued by Mr. Platt on the preparation of preliminary plans for the proposed gallery building, made possible by the raising of $10,000 by private subscription as noted in last year's report, and the plans could now be made ready for the beginning of construction within six months. It is estimated that three years would be required to erect the building. The movement for such a building suffered a severe loss in the death of Senator Henry Cabot Lodge, who was deeply interested in the national collections of art and history. In 1924 he offered in the Senate an amendment to the deficiency appropriation bill providing $7,000,000 for a gallery building to accommodate the collections not only of art but also those of American history now housed in the National Museum.

The annual meeting of the National Gallery Commission was held on December 9, 1924. The report of the secretary mentioned the following action on problems considered at last year's meeting: The approval by the Board of Regents of the commission's recommendation to include a division of historical architecture in the National Gallery of Art; the appointment of Mr. Charles A. Platt as architect of the proposed gallery building; and the approval by the commission of the inclusion in the prospective gallery of collections of both American history and art. The question of the acceptance of works of art by correspondence was discussed, and it was resolved that hereafter a majority of the advisory committee be required to examine personally all works of art offered the gallery before making recommendation. Mr. Edmund C. Tarbell was selected to fill the vacancy caused by the resignation of Mr. Edwin H. Blashfield. The annual election resulted in no changes in the officers or personnel of the commission for the coming year. Appreciation was expressed of the activities of the American Federation of Arts and the Federation of Women's Clubs in behalf of the proposed new art building.

Permanent accessions to the gallery during the year included seven paintings, several pieces of sculpture, and a collection of French and other art objects, part of the bequest of the late Rev. Alfred Duane Pell. Several loans were accepted and about an equal number withdrawn during the year, and five paintings belonging to the gallery were lent for exhibition elsewhere. Four special exhibitions were held during the winter and early spring, catalogues for which were issued by the gallery.

FREER GALLERY OF ART

The year's work in the preservation of the collection included the remounting of a considerable number of prints, bringing the total number of objects in the print collection which have been put in final condition to over 1,000. Additions to the collection included a pastel by Whistler, an Indian bronze, Indian paintings, Chinese bronzes, a Chinese painting, and Near Eastern pottery. A list of the Freer Gallery collection of paintings, pastels, drawings, prints, and copper plates by and attributed to American and European artists, together with a list of original Whistleriana, was in press at the close of the year.

Ninety books and periodicals and 127 pamphlets were added to the library. Several hundred photographs and a number of lantern slides were made and sold to persons requesting them. An increased number of requests have reached the gallery for translations of Chinese, Japanese, and Tibetan inscriptions, and for other information bearing on the work of the gallery.

The total attendance for the year was 109,862. Of this number, 431 used the study rooms to view objects not on exhibition or to consult reference works in the library.

The gallery's archeological expedition in China was still in the field at the close of the year, and a condensed report on its work will be submitted later for publication in the Smithsonian annual exploration pamphlet.

BUREAU OF AMERICAN ETHNOLOGY

The function of the Bureau of American Ethnology as defined by Congress is to conduct ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archeologic remains. The results of these researches are published in technical monographs as well as in articles of a more popular character, and reliable information regarding the American Indian is thus made available for students. The aboriginal Indian culture is rapidly disappearing through contact with the white man's civilization, and when the older men of the tribes who know the rites and customs of their fathers have passed away, much of the ancient lore will be lost forever. The bureau is recording as much as possible of this material before it is too late to secure it.

An important Indian culture area is that of the southeastern United States, and the bureau has recently begun an archeological reconnaissance, so far as its resources will permit, in Florida, Alabama, Tennessee, and Mississippi. It is possible to reconstruct from

historical sources the main outlines of this Gulf culture, but much more information is needed regarding the rituals, idols, ceremonial objects, and symbolism on pottery before we can form a complete idea of this interesting aboriginal culture.

Dr. J. Walter Fewkes, chief of the bureau, spent several weeks in reconnaissance near Florence, Ala., where a number of interesting Indian mounds were located which will be submerged with the completion of the Wilson Dam at Muscle Shoals. Mr. Gerard Fowke continued the excavation of two of these mounds, which yielded a considerable collection including rare copper ornaments, among the largest known from the Tennessee Valley. Doctor Fewkes also prepared during the year an illustrated report on a collection of archeological objects from Youngs Canyon, near Flagstaff, Ariz., a region of great importance in determining the relationship of the various culture areas of the Southwest.

During the past year, Mr. Earl H. Morris, under the direction of Doctor Fewkes, did necessary repair work on the famous tower of the Mummy Cave House in the Canyon del Muerto, Ariz., which will go far toward preserving what is considered one of the finest examples of aboriginal architecture in the entire Southwest.

Dr. John R. Swanton discovered further material bearing on the social and religious life of the Creek Indians, and embodied this information in papers now being prepared for publication. He also prepared a paper as a result of his recent study of the smaller culture centers within our present Gulf States, entitled "Culture of the Southeast" and a short report on the "Ethnology of the Chickasaw," and he continued work on the now extinct Timucua language.

Dr. Truman Michelson continued his studies of the Fox Indians, transcribing and translating a number of texts relating to their customs and beliefs. He also renewed his researches among the Algonquian tribes of Iowa, spending part of the summer in that State.

During the year, Mr. John P. Harrington continued his work on the Burton Mound Indian village situated at Santa Barbara, preparing for publication the material resulting from last year's excavations in cooperation with the Museum of the American Indian, and carrying on additional excavations at the same site which have yielded much important material. In addition, he prepared a report on the archeology of the Santa Barbara region along both historical and archeological lines. Mr. Harrington also made an exhaustive study of the language of the Tulé Indians of Panama, eight of whom were brought to Washington by Mr. R. O. Marsh in October, 1924, and remained until January, 1925, thus giving him an excellent opportunity for this investigation.

In May, 1925, Mr. J. N. B. Hewitt left Washington for Brantford, Canada, to resume his researches among the six nations, or tribes, of the Iroquois. With the aid of the two best Mohawk informants available, Mr. Hewitt made a free English translation of one of the most important of the ancient rituals, and took up the literary interpretation, revision, and textual criticism of previously recorded voluminous Iroquoian texts. An interesting résumé of this work is presented in the report of the chief of the bureau which forms Appendix 4 of this report. Mr. Hewitt also visited the Chippewa of Garden River, Canada, and the Seneca in Missouri and Oklahoma.

During the year, Mr. Francis La Flesche completed his paper on two versions of the child-naming rite of the Osage Tribe. In May, Mr. La Flesche visited the Osages and remained through June working at the laborious task of properly recording the gentile personal names used by the full-blood members of the tribe and by some of the mixed bloods. Mr. J. George Wright, of the Osage Agency, cooperated in this work by giving Mr. La Flesche access to the records of his office. Mr. La Flesche collected during his stay in the region some interesting plants used as food or medicine among the Indians.

Miss Frances Densmore continued her special research on the music of the Indians during the past year, resulting in the preparation of five manuscripts comprising transcriptions of 69 songs, together with the original phonograph records and analyses of the songs, which were purchased by the bureau for future publication. Miss Densmore's manuscripts included also one on the uses by the Makah Indians of 26 plants in food, medicine, and dyes. She took advantage of the presence in Washington of the group of Tulé Indians, mentioned before in connection with Mr. Harrington's study of their language, to make a study of their music. Their favorite musical instrument was found to be the "pan pipe" of reeds, and they also used another reed instrument known as the "mouth flute" that had not before been observed in primitive music.

The publications of the bureau issued during the year consisted of two reports and one bulletin. Three other reports were in press at the close of the year. 7,354 copies of the publications of the bureau were distributed during the year.

INTERNATIONAL EXCHANGES

The total number of packages handled by the exchange service during the year was 468,731, weighing 506,164 pounds, an increase in the number of packages over last year of 8,073 and a decrease in weight of 60,943 pounds, due to the smaller size of the packages of publications received for transmission through the service.

Fifty-eight full sets of United States official documents and 40 partial sets are now sent regularly to depositories abroad. This is a reduction of one full set from last year and an addition of two partial sets. At the request of New Zealand, a partial set is now being sent to the General Assembly Library instead of a full one and the Stadtbibliothek of the Free City of Danzig has been added to the list of those receiving partial sets. The immediate exchange of the Official Journal has been entered into during the year with India and the Free City of Danzig.

A committee of experts on the international exchange of publications was called together by the committee on intellectual cooperation of the League of Nations at Geneva, July 17–19, 1924. Mr. H. W. Dorsey, chief clerk of the Institution, represented the Smithsonian on this committee. The committee recommended an additional protocol to the Brussels convention of 1886, enabling the states that are not yet parties to the convention to adhere thereto with reservations. The committee also gave consideration to various other matters looking to the improvement of the international exchange service and the extension of its activities.

NATIONAL ZOOLOGICAL PARK

I regret to have to record the death on November 3, 1924, of Mr. N. Hollister, for eight years the able superintendent of the park. Dr. Alexander Wetmore succeeded Mr. Hollister and served until April 1, 1925. On that date he was appointed an assistant secretary of the Smithsonian Institution, and Dr. William M. Mann, entomologist of the Department of Agriculture and widely known as an explorer in the interests of zoology and entomology, was appointed superintendent of the park on May 13, 1925.

The collection of animals in the park has been somewhat diminished in value during the year by a number of deaths among the older animals. This loss has been offset to a certain extend by the accession of 130 animals presented by various donors and 70 mammals and birds born or hatched in the park, but among the older stock lost were many valuable specimens that can be replaced only by purchase, and funds for this purpose are very limited. The more notable of the new gifts to the park included a splendid young male chimpanzee, from Mr. Victor J. Evans, and a Bateleur eagle, an Abyssinian falcon, and two South American stone plover from Mr. B. H. Swales.

The total number of individuals in the park collection at the close of the year was 1,620, 25 less than reported last year. The species represented, however, show an increase of 17 due to judicious selection and purchase of small species offered for sale at moderate prices.

The attendance for the past year was the highest the National Zoological Park has even known, the number of visitors recorded reaching a total of 2,518,265.

During the year the animal warehouse, construction of which was begun last year, was completed and put into service, a double bear cage of steel was erected, and many minor repairs were made on old buildings. In many instances these, even when carefully repaired, are poorly adapted to the present needs of the park and should be replaced by new ones that would not only safely and comfortably house their inmates, but would also better accommodate the great throngs of visitors to the collections. The buildings most urgently needed are a house for birds and one for reptiles.

ASTROPHYSICAL OBSERVATORY

Much progress has been made during the year in the study of the sun and its application to weather forecasting. Through the generous assistance of Mr. John A. Roebling, the experimental forecasts by Mr. H. H. Clayton for the city of New York, based on daily telegraphic reports from the observing stations in Chile and Arizona, mentioned in last year's report, were continued. Four papers have been issued in the Smithsonian Miscellaneous Collections, reporting in detail on the results of this work. While it is still largely experimental, the forecasts have certainly indicated a moderate degree of foreknowledge. A higher degree of accuracy in the solar measurements upon which the forecasts are based will undoubtedly lead to better results, and to this end the staff of the observatory is now engaged in completely revising the methods of observing, measuring, and recording the solar radiation. The station at Harqua Hala, Ariz., has been removed to Table Mountain, Calif., to obtain better atmospheric conditions and greater convenience of access. This transfer was made possible through the aid of Mr. Roebling.

The director occupied the Mount Wilson station during the summer and autumn of 1924. He continued work on the three projects outlined in last year's report with the following results: The solar cooker was greatly improved; measurements of atmospheric ozone were made with the Fabry type of apparatus; and new devices were tried in stellar energy spectrum measurements which seem to open the way for great advances in that line.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

Attention is again called to the urgent need of financial assistance to enable the International Catalogue to resume publication of the 17 annual volumes which for so many years were depended on to

furnish references to the world's literature of science. Ever since war conditions made it necessary to suspend publication in 1921, it has been the hope that foreign political and financial conditions would improve sufficiently to enable the cooperating countries to again furnish the necessary funds through subscription as heretofore, but with the exchange rates of several of these countries now at a lower level than ever before, it seems that this hope will be futile for some time to come.

Although actual publication has ceased for the present, the organization is in no sense bankrupt, for, according to an agreement made at the Brussels Convention in 1922, the regional bureaus continue their work of assembling current bibliographical data, thus keeping the organization working, and when publication is resumed it is believed that new subscribers will purchase the back issues of the catalogue now held in storage. It would be difficult to find an object more worthy of endowment than this unique international, cooperative undertaking, for no similar enterprise has ever filled the place occupied by the catalogue and no new organization could hope to gain the official recognition held by the International Catalogue of Scientific Literature.

NECROLOGY

HENRY CABOT LODGE

Henry Cabot Lodge, United States Senator since 1893 and Regent of the Smithsonian Institution for 22 years, died November 9, 1924. Born in 1850, Mr. Lodge was admitted to the bar in 1876, and during the early part of his career served as editor of the North American Review and later of the International Review. He next served for two years as a member of the Massachusetts House of Representatives, and in 1887 was elected to Congress, where he remained until 1893. In this year began his career as a United States Senator, to which office he was continually reelected until the time of his death, and the last term for which he was chosen to represent the people of Massachusetts would not have expired until 1929.

Mr. Lodge was a very influential member of the Senate, having served as Republican floor leader from 1918 until the year of his death. In addition to his political activity, he was the author of many important historical works and essays.

Through his long period of membership on the Board of Regents and his interest and active participation in the affairs of the Institution, Senator Lodge had become a valued adviser, and his loss is keenly felt by the board and the officers of the Institution.

NED HOLLISTER

Ned Hollister, superintendent of the National Zoological Park since October 1, 1916, and one of the foremost mammalogists of the world, died on November 3, 1924.

Mr. Hollister was born at Delavan, Wis., November 26, 1876, where he received his education and began the study of zoology. From 1902 to 1909 he conducted zoological field work for the United States Biological Survey in Texas, New Mexico, Alaska, British Columbia, Washington, Oregon, California, Utah, Nevada, Louisiana, and Arizona. In 1910 he began his connection with the Smithsonian Institution, being appointed assistant curator of mammals in the United States National Museum, which position he held until 1916 when he was selected for the responsible position of superintendent of the National Zoological Park.

In 1911, Mr. Hollister was a member of the Canadian Alpine Club expedition to explore the Mount Robson region of British Columbia and Alberta, and in 1912 he represented the Smithsonian Institution on the Smithsonian-Harvard expedition to the Altai Mountains, Siberia and Mongolia. The results of Mr. Hollister's scientific work have appeared in the publications of the Institution and in various technical journals for many years. Besides over 100 minor papers on zoological subjects, he was the author of a number of large works, including The Birds of Wisconsin (1903); Mammals of the Philippine Islands (1911); Mammals of the Alpine Club Expedition to Mount Robson (1913); East African Mammals in the United States National Museum (vol. 1, 1918; vol. 2, 1919; vol. 3, 1923.) This last is probably Mr. Hollister's greatest contribution to science, being a complete technical account of the great collections made in East Africa by Theodore Roosevelt, Paul Rainey, and other collectors.

During Mr. Hollister's term of office as superintendent the National Zoological Park showed a steady growth and development, the collection of animals in the Park being greater in numbers and in scientific value than ever before, and the number of visitors to the park having increased steadily until it reached during the past year a total of over 2,500,000. It was largely through Mr. Hollister's efforts that Congress a few years ago provided funds for the purchase of a frontage of 625 feet at the Connecticut Avenue entrance to the park, thus insuring for the future a dignified and appropriate approach.

Mr. Hollister was a member of many scientific societies and editor of the Journal of Mammalogy.

WASHINGTON I. ADAMS

Washington I. Adams, who was connected with the Institution from 1896 until his retirement in 1924, died at Watertown, Mass., April 19, 1925. Mr. Adams came to the Institution as chief clerk of the International Exchange Service, which position he held until 1905 when he was appointed chief disbursing agent, a position he held until his retirement. Mr. Adams's duties and responsibilities were greatly increased in recent years due largely to the receipt of the Freer bequest of over $3,000,000.

NEWTON P. SCUDDER

Newton P. Scudder, assistant librarian of the National Museum, died on May 19, 1925, two months after his retirement from active service. Mr. Scudder was given an appointment as clerk in 1882 and five years later was made an assistant librarian in the Museum, which position he held until his retirement on March 9, 1925.

Mr. Scudder was born in Brooklyn, N. Y., in 1853, and graduated from Wesleyan University in 1879. His first work was with the Bureau of Fisheries, and under its auspices he made a trip to the halibut banks. As a result of this investigation two papers by him on "The Halibut Fishery, Davis Strait," and "The Salt Halibut Fishery," were published by the Bureau of Fisheries. Following this work, Mr. Scudder came to the Museum library, where he remained until his recent retirement.

Respectfully submitted.

CHARLES D. WALCOTT, *Secretary.*

APPENDIX 1

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operations of the United States National Museum for the fiscal year ended June 30, 1925.

The appropriations for the maintenance of the National Museum for the fiscal year amounted to $584,792, an increase of $52,396 over the previous year. This increase, however, is more apparent than real so far as providing additional funds for the operation of the Museum is concerned, since $44,534 of the amount represented the sum required for increase of salaries from the inauguration of the schedules authorized by the reclassification act of 1923, which became effective July 1, 1924, while subsequent reallocations of employees by the Personnel Classification Board resulted in increasing salary allotments approximately $9,000 beyond the estimated amount. It thus transpired that the amounts available for actual operating expenses were less than during the previous year. Moreover, the reclassification act had the effect of reducing the amount provided for printing and binding since increase in salaries in the Government Printing Office inaugurated under it resulted in increased cost in printing, thus reducing the production value of the sum allotted for that purpose to the Museum.

Attention has been called repeatedly in these annual reports on operation to the great disproportion between the increase in the appropriations provided for the maintenance of the Museum and the increase in the size of its collections, as well as in the quantity, scope, and importance of its exhibition and research work and its service to the public at large. Through the unselfish efforts of the personnel and the practice of the most rigid economy it has been possible until now to maintain a high degree of efficiency, but the very fact of its steady growth will curtail the usefulness of the Museum as a factor in the field of science and education unless it can be assured of sufficient funds to cover its natural and proper expansion. There is urgent need now for additional funds for operation, and for reasonable sums for the purchase of specimens and for use in minor explorations. Rich additions to the collections are received each year through specimens deposited by Government agencies or presented by private donors. Definite gaps in all lines exist, however, that may be filled only by purchase of desirable

things or by small sums spent in field work to acquire them. Specimens actually needed are obtainable usually only at long intervals and if such opportunities are allowed to pass further chance to acquire them may be remote or uncertain. Highly desirable things offered at reasonable prices are refused nearly every week. The Institution should have available moderate funds that might be used for such purposes.

Need of funds for exploration is also imperative since through this means only is it practicable to obtain data and information of importance in connection with many objects desired for the collections. Definite research on the part of experts is often required to clear up doubtful points in source or relationship of many things.

More and more each year the National Museum is approached for authentic information in a wide range of subjects not to be obtained elsewhere. Its vast collections of carefully arranged and classified specimens afford a full record of industrial, social, and esthetic progress as well as of painstaking and exhaustive research work in the natural sciences. In it are gathered the results of governmental activities and private donations aggregating many millions of dollars. The Museum collections serve as a foundation for the economic work of such great Government organizations as the Department of Agriculture, the Geological Survey, and others, and the members of the scientific staff assist materially in the work of these institutions through identification and report on the various objects with which they are concerned. To maintain its position of constantly increasing importance in the field of Government service and to fulfill its function as a truly national museum, it is absolutely necessary that adequate funds be provided for its proper maintenance. It is sincerely hoped that its needs in this direction will be recognized and provided for by suitable appropriations.

Final establishment of the salary schedules under the reclassification act brought the salaries paid to members of the scientific staff in the National Museum in most cases to a parity with those doing similar work in other departments, and has thus in large part corrected a lamentable condition in which members of the staff were paid at rates established many years ago and which in modern circumstances had become wholly inadequate. The increased salaries available have allowed the filling of several vacancies that have existed for some time and to fill which there were no suitable candidates at previous rates of pay. Adjustments in allocation in certain positions still remain to be made before the scale in force is just and equitable in all its features, as it is felt that the rates assigned in some positions do not correspond with the grades or emoluments applied to similar positions in other branches of Government service.

The financial assistance accorded to members of the scientific staff has been greatly appreciated but attention is drawn to the necessity of keeping this matter in mind so that faithful service may be further rewarded. Provision is made in the reclassification act for increase in salary to the average amount in the various grades, provided a suitable record of efficiency is maintained. Two surveys of efficiency of the entire staff have been made in accordance with regulations laid down by the Personnel Classification Board, and in further accordance with the regulations of that board the ratings assigned have been transmitted to the staff. It is highly gratifying to record that with very few exceptions these ratings have been excellent and have been of such a degree that they warrant promotion. Under existing appropriations, funds for the proper advancement indicated are not available. The matter is earnestly recommended for serious consideration to the end that money may be provided to make the necessary increase. Such action has been taken in other departments and it is sincerely desired to avoid falling behind in this respect as was the case under former salary regulations.

Though not universally recognized as an element in educational activities, the National Museum fulfills a threefold function in that field. Through the care and preservation of its vast and inestimably valuable collections and their careful arrangement and classification, it affords a visual record of progress and development of our own and foreign peoples, of important advances in the history of our country, and of achievements in science, industry, and art. As a museum of research it affords opportunity to the trained specialist and to the serious student to pursue studies of all kinds with facilities not elsewhere obtainable. It is seen as a museum of education by the visiting public, who come to examine the many treasures in the exhibition halls, while through its publications, correspondence, and distribution of duplicate specimens it reaches thousands who are not so fortunate as to be able to visit its halls. It may be safely said that no textbook, work of reference, or encyclopedia of facts has been issued in this country in recent years that has not based some of its statements on information originating in the National Museum.

As a modern feature for the dissemination of knowledge may be mentioned the radio program of the Smithsonian Institution organized last year which has continued under the direction of Mr. Austin H. Clark of the Museum staff in cooperation with the broadcasting station WRC, Radio Corporation of America. In all, 28 talks, of 15 minutes each, were given during the winter, 10 being by members of the staff of the Institution, including 7 from the Museum. Four of these talks were broadcast also by stations WJY and WJZ in New York City, reaching thus a broad audience. The talks, which began October 2, 1924, and were concluded on May 14, 1925, were

delivered by 25 individual speakers. The subjects chosen came from a wide range in the field of science and proved highly popular as attested by the many letters received from listeners far and near. Some of them have been published in permanent form. Possibilities in the spread of authentic scientific information through this means are great, since in this way informational talks prepared in an interesting manner go out to an extended audience fully appreciative of what they hear. It is possible thus to present the newer facts and changing aspects of science in a manner unequaled by other means.

As was anticipated when the Loeb collection of chemical types was placed under the special charge of a paid curator, splendid progress has been made. Through the activities of Mr. O. E. Roberts, jr., the curator, and cooperation on the part of many chemists and organizations, 616 new specimens have been added to the collection during the year. The importance of such a collection is only just beginning to be realized, but the interest already taken in it by specialists in chemical research work in indicative of the important results eventually to be achieved.

COLLECTIONS

The results of the year show a most satisfactory growth in the collections, the total number of specimens received amounting to 363,490, while additional lots of material received for examination and report numbered 1,232. The number of additions exceeds slightly the very high mark attained last year, while material for report also shows a slight increase. The increases are highly gratifying and have brought a great amount of extremely valuable material to the collections.

As in previous years, duplicate specimens were distributed as gifts to educational institutions or utilized in the making of exchanges for specimens needed toward completing the collections. The material thus disposed of amounted to 231,244 specimens, of which 2,099 represent gifts. An additional lot of material, comprising 33,966 specimens, was distributed in the form of loans to specialists and students for study and identification.

The following résumé of the more important accessions received during the year is submitted by the heads of the several departments or divisions of the Museum:

Anthropology.—The department of anthropology reports a year of satisfactory progress in all lines of its activities.

In the division of ethnology there was received a unique series of objects illustrating the material culture of the Indians of eastern Panama as a result of the explorations of the Marsh-Darien expedition cooperating with the Smithsonian Institution. This collection is

regarded as of such scientific interest that a special paper describing it has been prepared and submitted for publication. Another accession of particular beauty and rarity was the remainder of the collection of California Indian baskets bequeathed by the late Miss Ella F. Hubby, of Pasadena.

Among additions in American archeology may be mentioned collections from Town Creek, Ala., on the site of Wilson Dam, Muscle Shoals, and from Weeden Island, St. Petersburg, Fla., collected by Gerard Fowke and Dr. J. Walter Fewkes, respectively, and transferred from the Bureau of American Ethnology. The first of these is especially valuable, since it comes from a locality that will be covered by water when impounded by the dam.

The accessions in the division of Old World archeology include a copy of the Welsh version of the Bible from David W. Evans and numerous Egyptian and Graeco-Roman antiquities and ancient glassware loaned by Edward Sampson.

In physical anthropology there were added several casts of the remains of the famous Trinil man of Java, *Pithecanthropus erectus*, received from Dr. Eugene Dubois, who has been engaged in exhaustive studies of this highly important fossil. Also there has been received from the British Museum a cast of the skull found recently at Broken Hill in Rhodesia. Other important casts represent remains of ancient man from Czechoslovakia. These will all be of great assistance in studies of ancient man. The Bureau of American Ethnology transferred skeletal material from Florida, and the National Geographic Society presented important skeletons found in excavations at Pueblo Bonito and Pueblo del Arroyo, New Mexico. The Buffalo Society of Natural Sciences donated a collection of Iroquois skeletal material collected in Erie County, N. Y.

Mr. Hugo Worch has added to the Worch collection of pianos four splendidly decorated harpsichords of the sixteenth and seventeenth centuries. Miss Frances Densmore completed her study of the collection of musical instruments and submitted a manuscript descriptive of it.

The ceramic collection was augmented by a collection of English porcelain and glass, gift of Mrs. Frances Roome Powers.

In art textiles, the valuable laces of the late Mrs. H. K. Porter were continued as a loan by her daughter, Miss Hegeman. By bequest of the late Miss Emily Tuckerman, all specimens belonging to her on deposit in the Museum were made a gift. The Misses Long contributed several fine specimens of embroidery and lace.

The department profited especially through explorations by the Bureau of American Ethnology, the National Geographic Society, and the Marsh-Darien expedition. Neil M. Judd, in charge of

the excavations carried on under the auspices of the National Geographic Society at Pueblo Bonito, remained in the field for several months and secured excellent collections and highly important information. Henry B. Collins, jr., conducted explorations at ancient village sites in Mississippi, where valuable studies have resulted from intensive work in the field.

Biology.—Increase in the collections in the various divisions of this department have equaled and in some cases have excelled those recorded for the previous year. Of outstanding interest is the collection of coleoptera and mollusks that came to the Museum by bequest of the late Col. Thomas Lincoln Casey. The beetles alone in this collection are estimated at approximately 90,000 specimens representing 16,000 species of which 5,000 were described by Colonel Casey and are represented by the types.

The large collections presented by the National Geographic Society as the result of expeditions in China by Dr. J. F. Rock and Mr. F. R. Wulsin include a total of over 4,500 specimens of vertebrates and 68,000 plants, a wonderful store of rich material that has added greatly to the representation from that area, for, in addition to a number of forms previously unknown to science, there are in the collection many species not before represented in this institution. Additional collections from China have come through the continued efforts of Rev. D. C. Graham in western Szechwan, which have added vertebrates and valuable insects. China has been further represented in our accessions by material collected by A. deC. Sowerby, presented through the continued interest of Mr. R. S. Clark.

Mr. B. H. Swales has continued his important additions to the collections of birds by the purchase of a considerable number of species not previously represented including a number of rarities from Madagascar. Further acquisitions through the interest of Dr. Casey A. Wood have resulted in additional specimens from Fiji. Dr. Hugh M. Smith, now in Siam, has begun presentation of valuable material from a region almost unknown in our collections and has included among other things in his first sending a highly valuable lot of marine invertebrates.

Valuable collections of fishes have come from the H. K. Mulford Co., of Philadelphia. Certain important specimens have been purchased for the collections of mollusks from the income provided for that purpose by the Frances Lea Chamberlain fund.

In the exhibition halls there was installed a new group of Rocky Mountain goats prepared from material collected by Secretary and Mrs. C. D. Walcott; the case represents a family of four with an appropriate background of rockwork. A number of older mounts of other mammals have been replaced by material prepared by

modern methods and additions have been made to the collections exhibiting the local fauna. A second group not quite completed is that of the dik-dik, a diminutive antelope from Africa.

Geology.—Although a decrease is shown in the number of accessions and amount of material received in this department as compared with 1923–24, reference to earlier reports shows the present year to be an average one, with a total of 198 accessions, aggregating 79,674 specimens.

The paleontological collections are again the chief beneficiaries, notable among the acquisitions being the results of Secretary Walcott's field work for the past four years, as well as collections made by Doctors Bassler, Resser, and Ulrich in the summer of 1924. Gifts also materially increased the collections of invertebrate fossils, particularly those of the Mesozoic and Cenozoic periods, and one bequest added many thousands of specimens, including types.

In vertebrate paleontology the most important acquisition is a series of footprints from Permian deposits secured by Mr. C. W. Gilmore from the Hermit Trail, Grand Canyon National Park, working under the auspices of the National Park Service. Dr. J. C. Merriam, of the Carnegie Institution, of Washington, who was instrumental in perfecting the arrangements under which this material was secured, supplemented it by additional specimens taken personally. The fossil cetacean collection has also been materially increased and is now thought to be probably the largest and best preserved assemblage of these forms in any American institution.

A series of unusual forms of stalactites and stalagmites from Carlsbad Caverns, New Mexico, presented by the National Geographic Society, permitted the installation of an important addition to the exhibits showing cave phenomena.

In the field of applied geology the most important material received was that obtained by Assistant Curator Foshag while working with a United States Geological Survey field party in New Mexico. Doctor Foshag also collected much mineralogical material needed for the study collections. A few striking exhibition specimens of ores were obtained from various sources.

Col. W. A. Roebling was the chief contributor to the mineral collections, 6 accessions comprising 51 specimens being credited to him during the year. The most notable of these is a group of axinite crystals thought to be the largest of this mineral yet found.

A crystal of the new mineral, afwillite, donated by Mr. Alpheus F. Williams, is of particular interest in being one of the type lot which consists of less than a pound of the material. Notable specimens for exhibition were furnished through Mr. F. L. Hess, of which a group of large wulfenite crystals from Mexico, and a mass of pink muscovite and amblygonite from New Mexico are prominent.

Through the interest of Mr. Worcester R. Warner and the courtesy of the Fukushima Co. (Inc.), New York, the department of geology has been privileged to exhibit a crystal ball of unusual size and perfection, weighing 110 pounds and measuring 13¼ inches in diameter, which is said to be the largest of its kind known. This has attracted much attention from visitors.

Exchanges have added materially to the collections in all divisions of the department, both for exhibition and study, and a few objects have been acquired by purchase. Several additions have been made to the meteorite collection, consisting chiefly of fragments of moderate size, which, while important from a scientific standpoint, add little to the exhibits. A number of gems have been added to the Isaac Lea collection through the Frances Lea Chamberlain fund.

Secretary Walcott continued his researches in British Columbia; Dr. R. S. Bassler, in Tennessee, in cooperation with the geological survey of that State; Dr. C. E. Resser, in the Rocky Mountain region of the United States; and Dr. W. F. Foshag was detailed to accompany a geological survey party in New Mexico. Mr. C. W. Gilmore spent some weeks in the Grand Canyon National Park, under the auspices of the National Park Service.

Work on the exhibits has been chiefly confined to cleaning and rearranging, no important changes having been made. In stratigraphic paleontology much time and effort have been consumed in expansion of the collections and in general cleaning and rearranging of the paleobotanical collections. The efforts of the force in vertebrate paleontology have been confined almost wholly to the preparation of the huge dinosaur skeleton, collected last year, with satisfactory results.

Research work has continued to the extent permitted by other duties.

Arts and industries.—Growth in this department has been satisfactory in the main though hampered in many lines by crowding. Materials for accession are selected with great care, but so much that is wholly desirable is offered that available facilities for exhibition are greatly overtaxed.

In the division of mechanical and mineral technology there was a slight falling off in the number of accessions received and a material decrease in the number of specimens catalogued during the year, due, primarily, to a lack of exhibition and storage space. This condition is aggravated more and more each year and will lead to further decrease in the rate of acceptance of objects for the collection since now choice may be made only of things urgently required.

In the transportation section one early type of automobile was received, a Knox car made in 1901, presented by Mrs. Lansing Van

Auken, Watervliet, N. Y. The signal section of the American Railway Association added to its series of specimens, showing developments in railway signaling, 16 objects that indicate some of the early efforts in block signaling. The Buda Co., of Harvey, Ill., presented a full-size gasoline automobile engine operated by an electric motor specially arranged for exhibition. By pressing a button it may be put in operation, thus permitting study of many of the working parts in action. Mr. Henry Ford presented a specially prepared exhibit of the planetary transmission used in the Ford automobile. As this is one of the distinctive types of automobile transmissions it will form an interesting part of an exhibit now under way designed to illustrate the various fundamental units composing the automobile.

The Portland Cement Association, of Chicago, Ill., through its local office, presented a full-size photographic copy, suitably framed, of the original patent on Portland cement granted by King George III to Joseph Aspdin in 1824. The presentation of this interesting paper was made in the presence of about 12 officials representing various departments of the Government interested in Portland cement and was accepted on behalf of the Museum by Secretary Walcott. The framed copy now hangs in close proximity to the exhibit on Portland cement in the division of mineral technology.

The collections under the supervision of the curator of textiles, which, besides textiles, embrace wood technology, foods, animal products, organic chemistry, and medicine, were increased by many gifts and by transfer of material from other Government bureaus, amounting in all to over 8,800 objects. A statement concerning the most important of these follows:

Series of industrial specimens illustrating many branches of rubber manufacture, the manufacture of sealing wax, and a model showing the preparation and dyeing of furs were added to the collections from the field of industrial chemistry. The textile collections were increased by gifts of fibers, yarns, silk and cotton dress and drapery fabrics, wool fabrics, mohair plushes, and machine embroideries; also many examples of modern handicraft. To the collections arranged to show the importance of wood and the industries based thereon were added veneered panels of wood used in the furniture industry, showing the different kinds of finishes used, a series of specimens demonstrating the manufacture of lead pencils, and a large timber of Douglas fir to represent an important product of the forests of the Pacific Northwest. The collections added to the division of medicine were chiefly in the field of public health, and consisted of models and posters showing advances in sanitary science. Specimens of materia medica and numerous objects asso-

ciated with the history of medicine in America were among other additions to this division.

Work of the devision of graphic arts continued mainly along lines developed in past years, and consisted of improving and completing existing series of specimens and the continuance of special exhibitions. Fourteen of the latter held during the year attracted favorable attention. Valuable additions to exhibit materials have been received or promised as a result of these exhibits.

One important new exhibit of microengraving has attracted much attention. It consists of "The Lord's Prayer" engraved on glass in a square space about $\frac{1}{1\,8\,5\,0\,0}$ of an inch on a side, so arranged that it is viewed under a miscrope through the eye of a needle. The entire exhibit was prepared and presented by Alfred McEwen, of New York City.

The exhibit of mezzotints has been completely rearranged, with additions of new specimens to the historical series and of two series of plates and prints to the technical set, so that it now presents a clear idea of the early and modern methods of engraving mezzotints.

The collection illustrating methods used in printing for the blind has also been greatly improved by the incorporation of additional material which gives a clear idea of the method of making and printing the special plates required in this work and the manner in which the characters are read by the blind.

Three Babylonian tablets about 4,000 years old, inscribed with cuneiform writing, acquired by purchase, have been placed with the exhibits on the history of writing where they make an interesting addition. Two of these of small size are of baked clay and represent a skillful form of writing. The other represents the effort of a schoolboy learning to write, and, while crude, is of considerable interest. Tablets of this latter kind are very rare, as they are of unbaked clay and were not intended to be permanently preserved.

From Mr. B. M. Comerford, of Washington, D. C., were received four examples of the rare and beautiful art of fore-edge decorating, which consists of painting on the small portions of the leaves of a book that are exposed when the back is pushed out of normal position. The picture disappears when the book is closed. This art is said to have been originated by Samuel Mearne, who is reported to have practiced it as early as 1662.

The aquatone process, which was mentioned in last year's report as a new and beautiful development among modern photomechanical processes, is now represented by an exhibit indicating the technical steps in the process of preparing and printing such a plate. This is the gift of William Edwin Rudge, of New York, and shows well the simplicity of the process and the beauty of the results obtained.

The two traveling exhibits prepared by the division have been out almost continuously, and have been shown by various art museums and graphic art organizations in the eastern half of the country, including those in Milwaukee, Wis., Brooklyn, N. Y., and Houston, Tex., as well as many intermediate points. Four other smaller exhibits are being prepared, which likewise depict the technical side of graphic arts but on a smaller scale. These consist of 25 mats, measuring 14 by 17 inches, weighing approximately 30 pounds, that can be shipped by mail at very small expense. The larger exhibits, which weigh 320 and 430 pounds, respectively, are forwarded by express.

The collection of photographs in the section of photography is becoming one of the most important public collections in the country, due to the efforts of A. J. Olmsted, custodian, and Mr. Floyd Vail, of New York City.

History.—The additions to the historical collections surpass both in number and scientific importance those received during the previous year. The military collections have been increased by the addition of a number of objects of special interest, among which are a presentation sword, flags, uniforms and accessories, and medals and badges owned by Lieut. Gen. Nelson A. Miles. The sword was presented to General Miles in 1887 by citizens of the State of Arizona in recognition of his services in connection with the capture of the Indian chief, Geronimo, and his band of hostile Apaches. The medals and badges include the Congressional Medal of Honor and the badge of the Society of the Cincinnati. An object of special interest in this connection is a large heart-shaped shield of silver and bronze which was presented to General Miles by the officers of the Fifth United States Infantry. These objects have been received by the Museum from Mrs. Samuel Reber and Maj. Sherman Miles, United States Army. A number of presentation and service swords owned during the nineteenth century by Maj. Gen. Frank Wheaton, United States Army, have been presented to the Museum by Mrs. Frank Wheaton. From Gen. John J. Pershing was received a number of military flags, maps, and posters, and the office desk and accessories which he used at the headquarters of the American Expeditionary Forces at Chaumont, France, during the World War.

The naval collections have been increased by the addition of a sword and two uniform coats owned during the early part of the nineteenth century by Commodore Samuel Woodhouse, United States Navy, which have been presented by Dr. Samuel W. Woodhouse, jr., and also by the transfer from the Navy Department of a series of 17 models illustrating the development of the United States Navy during the period from 1776 to 1920.

Through the cooperation of the United States Treasury Department, a number of valuable United States and foreign coins and medals have been added to the numismatic collections. Of special interest in this connection has been the transfer from the Treasury Department to the Museum of about 800 publications, forming a highly useful library, on the subject of numismatics.

The portrait collection was increased by the following additions: A portrait of Elizabeth Cady Stanton by Anna E. Klumpke was presented by the National American Woman's Suffrage Association; portraits of Gen. John J. Pershing and Marshal Ferdinand Foch were presented by the artist, Victor Perard. A portrait of President Warren G. Harding, by John Innes, showing the former delivering an address at Stanley Park, British Columbia, July 29, 1923, was presented to the Museum by the National Press Club, Washington, D. C.

EXPLORATIONS AND FIELD WORK

The greater part of the material added to the collections during the current year was as usual derived from expeditions and explorations under the auspices of private organizations and Government agencies.

In biology the National Geographic Society was a large contributor through its expeditions in China, in the Arctic, and in this country. From the former extremely valuable and extensive collections, comprising some 68,000 plants, over 1,600 birds, 60 mammals, and other specimens, were received from the society's expedition under Dr. Joseph F. Rock, principally from the Province of Yunnan. The bulk of the material collected by the society's expedition under Mr. F. R. Wulsin, which has been referred to in previous reports, was received during the past fiscal year. It comprised important and extensive collections of birds, mammals, reptiles, and fishes from inner Mongolia, the Alashan Desert, and Western Kansu, in the region of Lake Kokonor, northeastern Tibet, as well as from the Min Sha Range, which marks the boundary between the Provinces of Kansu and Szechwan. The specimens from this source are of particular importance, since they afford topotypes of numerous species described from Przevalski's famous exploring trip of 50 years before. They also include important ethnological material from a region not heretofore represented in this institution. The collections from these sources supplement those made by Mr. R. S. Clark and Mr. Arthur deC. Sowerby in 1908–9 in Kansu, Thansi, and Shensi, and the important collections made during the past year by Rev. David C. Graham in Szechwan. The latter were secured on a difficult trip to Songpan and the Yellow Dragon Gorge,

and comprise many specimens new to the Museum. Incidental to the Arctic explorations undertaken for the National Geographic Society in Bering Sea and Arctic America during the summer of 1924 by Capt. R. A. Bartlett, and by Mr. D. B. Macmillan in the *Bowdoin* in Greenland in 1924, some interesting zoological material was secured and presented to the Museum. In August, 1924, Mr. Paul C. Standley was detailed as a member of the Carlsbad Cavern expedition of the National Geographic Society, his association in the enterprise resulting in a collection of some 500 specimens of plants, many of species not previously known from New Mexico. A popular account of the vegetation of the Carlsbad Cavern region has been prepared for publication largely on the basis of this field work. Under the auspices of Mr. Robert S. Clark, several eastern Provinces in China were visited by Mr. Arthur deC. Sowerby, from whom extensive collections were received. Dr. Hugh M. Smith, who is at present fisheries adviser to the Siamese Government, forwarded interesting zoological material from that country.

As a result of his visit to Haiti during the spring of 1925, Mr. Gerrit S. Miller, jr., of the Museum staff, secured a collection of the extinct vertebrate cave fauna as well as miscellaneous specimens of the living mammals, birds, reptiles, insects, and plants of the island. Doctor Bartsch continued his experiments with Cerions, through the assistance of the Carnegie Institution of Washington, his visit to the experimental colonies of these mollusks planted on the Florida Keys resulting in the addition of some 2,700 specimens to the collections. In addition, through the cooperation of the United States Coast Guard, he was able, with the assistance of Mr. W. B. Marshall of the Museum staff, to do some dredging in the inner leads of Cape May and in the shallow waters off the coast of New Jersey, which resulted in adding quite a number of specimens from a region little explored. A survey of the fisheries of the Republic of Salvador, undertaken by S. F. Hildebrand and F. J. Foster, of the United States Bureau of Fisheries, at the request and at the expense of the Salvadorean Government, resulted in the collection and subsequent transfer to the Museum of a large collection of fishes and some crustaceans from the region referred to. Secretary Walcott's field work in the Canadian Rockies, in addition to yielding important paleontological material, added a number of valuable zoological specimens, some of which have been utilized in preparing a new exhibition group of Rocky Mountain goats in the Mammal Hall of the Museum. As the result of the detail by the Department of Agriculture of Mrs. Agnes Chase, of the Bureau of Plant Industry, to field work in the eastern highlands of Brazil, important botanical material was received for the National Herbarium.

Dr. William Schaus, honorary assistant curator of insects, through personal efforts raised the sum of $50,000 for the purchase of the famous collection of Lepidoptera gathered by M. Paul Dognin, Wimile, France, comprising a series of specimens highly valuable for studies of these important insects. Doctor Schaus went to France to supervise the packing of this collection for shipment to the museum, where it has been received, although not in time to be included in more detail in report.

The material secured by the Marsh-Darien expedition to Panama, referred to in last year's report, was received during the past year. It contained so much interesting ethnological material of a class not previously represented in our collections that it has been made the basis of a special report prepared by Mr. H. W. Krieger, curator of ethnology. Mr. Neil M. Judd, curator of American archeology in charge of the Pueblo Bonito expedition of the National Geographic Society, secured important collections for the Museum, and equally important material was secured by Mr. Gerard Fowke under the auspices of the Bureau of American Ethnology from burial sites near Muscle Shoals, Ala., which will soon be covered by water impounded by the Wilson Dam. Doctor Fewkes, Chief of the Bureau of American Ethnology, assisted by Mr. M. W. Stirling, of the department of anthropology, conducted an exploration of ancient Indian mounds at St. Petersburg, Fla., which resulted in important finds and material valuable to the collections. Dr. Aleš Hrdlička, of the Museum staff, assisted by a generous grant from the Buffalo Society of Natural Sciences, left in March for an extended trip through the Far East, Australia, and South Africa for the purpose of observing at first hand a number of peculiar races of men and to collect data on various discoveries of ancient man.

Under the auspices of the United States Geological Survey, Dr. W. F. Foshag, of the Museum staff, was enabled to make collections and to visit mineral properties in western Nevada where acquaintances made with mine owners and collectors will inure greatly to the benefit of the Museum. He also collected a series of minerals from California. Short trips to various localities in Maryland were made by Mr. Earl V. Shannon, of the Department of Geology, in cooperation with the State geological survey, and to Connecticut through an arrangement with the geological and natural history survey of that State, which resulted in necessary additions to our collections. Aided by grants from the O. C. Marsh and Joseph Henry endowment funds of the National Academy of Sciences, Secretary Walcott continued his field work in western Alberta for the purpose of completing his reconnaissance of the pre-Devonian

formations north of Bow Valley, the main objects of this year's work being to determine the correct geologic horizon of the Lyell limestone. Many attempts to do this during the past six years resulted in failure, and it really seemed that these great limestone beds were barren of fossils. In measuring geologic sections in the Tilted Mountain Area, however, interbedded bluish-gray layers containing fragments of Upper Cambrian trilobites were at last found, which proved their correct geologic horizon.

Dr. Charles E. Resser continued his field explorations of the Cambrian and associated formations. Dr. R. S. Bassler, in cooperation with the geological survey of Tennessee, continued his work in that State, and at the same time made collections of Mississippian fossils for the Museum. Mr. Erwin R. Pohl was detailed for a short time to make collections from the celebrated Rysedorph conglomerate of northern New York, which resulted in a good series of fossils for the Museum.

In cooperation with the National Park Service, Mr. C. W. Gilmore, curator of vertebrate paleontology, visited the Grand Canyon National Park, Ariz., for the purpose of accompanying the Doheny scientific expedition as an observer to investigate and make collections of fossil tracks exposed in the Coconino sandstone and to prepare an exhibit of the tracks in situ by the side of the Hermit Trail leading into the Grand Canyon. His trip was a most successful one in all of its aspects, a series of slabs some 2,000 pounds in weight and containing a splendid series of the fossil footprints being collected and shipped to the Museum. Dr. J. W. Gidley, of the geological staff of the Museum, visited the region around Melbourne, Fla., on two occasions during the year and secured an interesting collection of fossils. He also visited Adele, Iowa, for the purpose of studying the geology of a formation in which had been found certain human artifacts. Continuing the practice of previous years, Mr. Norman Boss made several short trips to the Calvert Cliffs along Chesapeake Bay in search of Miocene fossils.

A movement which promises important results to the Museum was inaugurated in the summer of 1924, when the Secretary of the Navy invited the Smithsonian Institution to participate in a conference of representatives of the executive departments and scientific establishments of the Government of the United States for the purpose of formulating plans for a naval expedition to undertake investigations in oceanography. Mr. Austin Clark, Dr. Waldo L. Schmitt, and Dr. Paul Bartsch, of the Museum staff, were designated as representatives of the Institution on this occasion, and at the close of the meeting Mr. Clark was chosen as representative of the Smithsonian Institution and its branches on an executive interim committee.

BUILDINGS AND EQUIPMENT

The various buildings of the Museum have been kept in good condition throughout the year through minor repairs, which have consisted largely in painting walls, ceilings, and floors, repairing cracks in plaster and cement surfaces, painting tin gutters and roofs, and work of a similar character. In the Arts and Industries Building new floors were laid in a few of the rooms and the ventilation improved.

In the Smithsonian Building it was necessary to replace with beaded sheets the entire plaster ceiling of the main hall on the third floor, occupied by the Museum's division of plants. The work was done partly by contract and partly by the Museum force.

Under a special appropriation for the purpose, four modern fire hydrants were installed under the direction of the District Commissioners in the Smithsonian Park.

The cost of heating for the year was considerably less than during the previous year, due partly to the lower cost of coal and partly to the fact that for the first time in many years it was possible to secure coal from the New River fields, which is better adapted to the heating apparatus. During the year, 3,292 tons of bituminous and 15.5 tons of anthracite coal were used. The total electric current generated during the year was 476,709 kilowatt-hours, at a total cost of 2.362 cents per kilowatt-hour, including labor, material, interest, and depreciation on the plant.

A total of 346.3 tons of ice were produced during the year at a cost of $2.309 per ton. A new compressor has been purchased which, with increase in the size of the condenser made during the year, will increase the capacity of the ice machine from 2 to 2½ tons per day. Even with the cost of the new compressor included, the cost per ton of ice will be under the wholesale price paid for ice by the Government.

During the year 18 exhibition cases and bases and 127 pieces of storage, laboratory, office, and other furniture were acquired by purchase and construction. Of the storage cases 11 were purchased and 116 built in the Museum shops.

MEETINGS AND RECEPTIONS

The Department of Agriculture was granted the use of the auditorium on October 27, 28, and 31 for a series of lectures by Dr. Vernon H. Blackman, of the Imperial College of Science and Technology in London, and on January 26 for a lecture on Agricultural Research and the Community, by Sir Daniel Hall, scientific adviser

to the Minister of Agriculture in England, all lectures being open to department workers and others. Other bureaus of this department using the auditorium were the Forest Service for a series of five lectures extending from October to June, the Bureau of Agricultural Economics for an exhibition and talk on the evening of April 20 by Mr. L. M. Estabrook, and the Federal Horticultural Board on June 29 and 30, for public hearings on fruit and rose stocks and the white-pine blister rust (when room 43 was also used), and again on September 20 by the same board for a conference on the white-pine blister rust quarantine. The auditorium and all committee rooms available were used for a national conference on utilization of forest products called by Secretary Wallace on November 19 and 20. On the afternoon of May 22, the department's post, Veterans of Foreign Wars of the United States, held memorial services in the auditorium in honor of the late Henry C. Wallace, and of the men of the Department of Agriculture who lost their lives in the World War.

The Department of Commerce occupied the auditorium for the National Radio Conference on October 7 and 8.

Dr. Aleš Hrdlička, of the Museum staff, gave two courses of lectures on anthropology during the period from October 24 to December 19—Man's Origin, on Friday afternoons in the auditorium, and Man's Physical and Physiological Characteristics, on Monday afternoons in room 43. These proved highly popular and were well attended.

Under the auspices of the School of Foreign Service, a series of 12 lectures were given in the auditorium by Dr. Edmund A. Walsh, S. J., of Georgetown University, on Russia in Revolution. These extended over a period from February 13 to May 15 and attracted much attention.

Associations and societies using the auditorium and room 43 for their annual meetings were the American Association for the Advancement of Science, December 29 to January 3, and the American Society of Mammalogists, April 8 to 10. The American Surgical Association met in the auditorium May 4, 5, and 6, and on the same dates the eighth annual meeting of the American Association for Thoracic Surgery was held in room 43. On the evening of January 2 the division of insects of the Museum was thrown open to members of the Entomological Society of America and the Association of Economic Entomologists, who were in attendance at the meeting of the American Association for the Advancement of Science.

In addition to the foregoing the auditorium was used on various occasions by the Wild Flower Preservation Society, the Audubon Society of the District of Columbia, the District of Columbia Dental

Society, Washington Society of Engineers, Washington Chapter of the American Association of Engineers, Practical Psychology Club, and the Boy Scouts of the third division.

Among the scientific and other societies that met regularly in room 43 were the Anthropological Society of Washington, the Entomological Society of Washington, the American Horticutural Society, and the Society for Philosophical Inquiry. Those using the room from time to time were: The Audubon Society of the District of Columbia during February and March for a series of talks by Dr. Alexander Wetmore; the Helminthological Society of Washington, when Prof. E. Brumpt, of the University of Paris, made an address; the Biological Society of Washington, for an address by F. Johansen; the Washington Chapter of the American Institute of Chemists; the directors and assistant directors of municipal playgrounds; the Camp Fire Girls, and the Camp Fire Guardians; and the Garden Homes Association for addresses intended "to encourage people to own a home and garden."

Mr. Chr. Thams, minister of the Prince of Monaco to France, on November 29 gave a lecture on the results of a journey undertaken into eastern Africa for the purpose of advancing the cause of conservation of wild life. The lecture was illustrated by a fine series of moving pictures impressive for their accuracy in revealing the habits of big game under natural conditions.

At the request of the Air Service Officers Reserve Corps, pictures illustrating the flight around the world were shown in the auditorium on the evening of April 8.

On the evening of May 2 the auditorium was used for a private showing of the historical picture made for the Commission of Relief in Belgium, before Secretary Hoover, who was chairman of that organization during the years of its operation from 1914 to 1919.

The auditorium was also used by the following: The Filipino Club of Washington, on the evening of July 3, for a meeting to celebrate the Fourth of July; El Club Cervantes, on the evening of December 20, to celebrate the centenary of the Battle of Ayacucho, the decisive battle in South America's wars for independence; Señor Don C. de Quesada, of the Cuban Embassy, on the evening of March 28 to celebrate the ratification of the treaty of the Isle of Pines and in honor of the Spanish War Veterans; the Cornell Alumni Society of Washington for a musical recital by Prof. Vladimir Karapetoff, of Cornell University, on the evening of April 23.

A national spelling bee was held in the auditorium on the evening of June 17, under the auspices of the Courier Journal and Louisville Times, of Louisville, Ky.

At the request of the Washington Chapter of the American Institute of Banking all of the exhibition halls on the ground, first, and second floors of the Natural History Building were opened on the evening of July 19 for a reception to the members of the Institute meeting in Washington at that time.

A joint meeting of the Anthropological Society of Washington, the Washington Academy of Science, and the Art and Archæology League, in conjunction with the Archæological Institute of America, was held in the auditorium on the evening of December 16, during which Count Byron Kuhn de Prorok gave a lecture on the "Carthage excavations, 1924," and "The dead cities of the Sahara." After the lecture a reception was held in the Art Gallery.

As one of the features of the meeting of the American Association for the Advancement of Science, on the evening of December 29, members and their guests were received in the Art Gallery by the Secretary of the Institution and Mrs. Walcott, at which time the entire first floor of the building was open. On the evening of June 10, the halls on the first and second floors were opened for a reception to the delegates of the National Association of Credit Men attending the convention held in Washington from June 8 to 13.

MISCELLANEOUS

For the first time in the history of the Museum the total number of visitors to the several buildings reached more than 1,000,000. These were recorded at the several buildings as follows: Arts and Industries, 304,858; Natural History, 557,016; Aircraft, 52,787; Smithsonian, 107,342; a total of 1,022,003.

The Museum published 5 volumes and 70 separate papers during the year while its distribution of publications amounted to 104,596 copies of books and pamphlets.

Additions to the library numbered 1,457 books and 1,894 pamphlets, mostly obtained by exchange or donation. With the funds available, only a few books could be purchased. Important contributions which have not yet been catalogued are the bequest by the late Col. Thomas L. Casey of approximately 4,500 books and pamphlets, mostly relating to Coleoptera, which were not entirely assorted until after the close of the year, and the transfer from the Treasury Department of 800 books and pamphlets relating to the science of numismatics.

Through the operation of the reclassification act, which became effective July 1, 1924, the salary standards in the Museum, particularly of the scientific staff, were materially improved and for the first time in many years every position in the Museum personnel was filled. The staff in the department of anthropology was completed

through the appointment of Mr. Herbert W. Krieger as curator and Mr. Henry B. Collins as assistant curator of ethnology. In the department of arts and industries Miss Aida M. Doyle was appointed aid to succeed Mr. Harry W. Rabinowitz, resigned, and in the division of history Miss Hortense Hoad was appointed aid.

In accordance with the special provision, included in the last appropriation act, creating a new Assistant Secretary of the Smithsonian Institution to have general charge of the museum interests of the Institution, including the United States National Museum, the National Gallery of Art and the National Zoological Park, the present incumbent was honored with appointment to that office on the 1st of April, 1925.

The Museum lost two employees during the year through the operation of the retirement act, viz, Mr. N. P. Scudder, assistant librarian of the Smithsonian Institution, in charge of the Museum library, and Robert Ghor, fireman. The only death among employees on the active rolls of the Museum was that of Israel Freeman, a laborer, employed in the Museum over 15 years, who died on July 16, 1924.

Respectfully submitted.

ALEXANDER WETMORE,
Assistant Secretary.

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit the following report on the affairs of the National Gallery of Art for the year ending June 30, 1925.

The activities of the gallery for the fifth year of its status as a separate administrative unit of the Smithsonian Institution correspond closely with those of previous years. The staff, which is limited to the director and the recorder, has been occupied during the year with the current work of the gallery; with the receipt, record, installation, and care of the collections, permanent and temporary; with the affairs of the gallery commission; with the development of an art library; and with promotion of the gallery's diversified interests. Other employees are: a stenographer, a gallery attendant, three watchmen, two laborers, two charwomen, and a carpenter who is assigned to the gallery by the National Museum when his services are required.

Additions to the gallery collections have fallen short of the average of previous years, the art works received by the Institution and awaiting approval by the advisory committee of the gallery commission not greatly exceeding a hundred thousand dollars in estimated value. This falling off is due, at least in part, to the shortage of exhibition space. Further important enrichment of the collections must thus await the erection of a gallery building, since collectors seeking a final resting place for their treasures consider very carefully their prospective installation and care. Mention may be made here of the fact that during the period between 1904 and 1924, the period during which suitable exhibition space happened to be available in the museum buildings, accessions by gift and bequest averaged in value approximately half a million dollars per year. With a gallery building such as the nation should have, it is believed that a million or millions annually would be within reasonable expectation. It is hardly within the range of possibility that a second benefactor will appear who is willing to present the Government with a building for his gift as did Mr. Freer, in order that the gift might be accepted.

During the year much attention has been given to the preparation of preliminary plans for a gallery building. Although Congress in 1921 set aside an appropriate site for a building, it was left

to the Institution to obtain funds necessary for the employment of an architect to prepare the preliminary plans. As the result of an appeal for this purpose by the Institution, $10,000 was raised by private subscription, and Mr. Charles A. Platt was selected to prepare the necessary plans. During the winter of 1923–24 Mr. Platt spent several months in Europe engaged in the study of the more important art galleries. The committee appointed by the Regents of the Institution to collaborate with Mr. Platt on the plans, which included in its membership Henry White, chairman, Frederic A. Delano, Herbert Adams, Gari Melchers, J. H. Gest, and C. D. Walcott, met in the Regents' room on February 13, 1925, and Mr. Platt presented the sketch plans, which he stated had been carried just far enough to be submitted for consideration by the Institution. Two hours were spent in examining the drawings, which comprised plans of the three floors, sections of the building, and a detailed drawing of the south front. Plans of a number of European galleries were submitted for comparison, and details of lighting and adaptation of space to the various requirements of the structure were considered. Mr. Platt stated that if the regents desired to have the work proceed the plans could be ready for the beginning of construction within six months, and that if appropriations were made available, the building could be completed in three years. It was expected by Mr. Platt that granite would be employed in the building. Questions of construction, employment of builders, and cost were discussed at length. Mr. Platt stated that the building, which as planned is 300 feet in width by 500 feet in length, will contain 10,000,000 cubic feet of stonework, and that the cost will hardly fall short of $1 per cubic foot. The committee accepted the plans as entirely satisfactory and reported to that effect to the Regents of the Institution.

The Platt drawings were first published in an article which appeared in the American Magazine of Art, March, 1925, where they were accompanied for purposes of comparison by the plans of a number of the principal art museums of both Europe and America. It is expected that the Regents of the Institution will, at the proper moment, present these preliminary plans to the committees of Congress having the erection of Government buildings in charge, for their consideration.

The death of Senator Lodge, a member of the Board of Regents of the Institution, who in 1924 offered in the Senate an amendment to the deficiency appropriation bill providing seven millions for a gallery building, leaves the movement without a militant head, but another will doubtless take his place since the urgent need of a building is now very generally recognized. The movement is re-

garded as having much added strength as a result of the fact that, as indicated in the Lodge resolution, the building when completed is expected to accommodate the collections of American history as well as those of art. The historical collections are of great popular interest, occupying to-day 120,000 square feet of floor space in the Smithsonian and the two Museum buildings—space urgently needed for the legitimate activities and vast collections of the several branches of natural science.

MEETINGS OF THE GALLERY COMMISSION

The annual meeting of the gallery commission was held in the Regents' room of the Smithsonian Institution, on December 9, 1924. The members present were: Gari Melchers, chairman, Herbert Adams, Joseph H. Gest, John E. Lodge, Frank J. Mather, jr., Charles Moore, James Parmelee, Edward W. Redfield, Charles D. Walcott, and William H. Holmes.

The very important problem of the inclusion in the prospective gallery building of collections both of art and history, as indicated in the Lodge resolution, was given attention and the view prevailed that it would be advantageous, at least for a time, to have the two departments in the same building, although definitely separated.

The question of the acceptance of works of art by the advisory committee through the medium of correspondence was raised, and after discussion it was resolved that hereafter, a majority of the advisory committee be required to personally examine the works before making recommendation. As a result of this action and the impracticability of calling the committee to Washington for the consideration of works offered from time to time, the practice has been adopted of having all works of exceptionally high merit offered to the gallery accepted by the Smithsonian Institution for submission to the advisory committee at the annual meeting of the commission or on occasions of particular importance, at especially called meetings of the committee.

Mr. Edmund C. Tarbell was selected a member of the commission to succeed Mr. Edwin H. Blashfield, resigned, and his appointment was recommended to the Board of Regents. Regarding the expiration of the three-year terms of three members of the commission, Messrs. John E. Lodge, James Parmelee, and E. W. Redfield, it was decided to recommend to the Board of Regents the reelection of these members for the succeeding term of four years. The present members of the executive and advisory committees and the present officers of the commission were reelected for the year 1925.

The Platt plans for the proposed National Gallery Building were then presented by the secretary and were given careful consideration by the members of the commission.

The advisory committee of the commission met in the gallery December 11, Gari Melchers, Miss Leila Mechlin, and W. H. Holmes being present. The following works were given favorable consideration:

Portrait of Hon. James R. Mann, by Gari Melchers.

Three paintings, the gift of Miss Emily Tuckerman: Hindoo Merchants, by Edwin Lord Weeks; Landscape (on copper), by Herman Saftleven; and The Refectory, by Eduardo Zamaçois.

The personnel of the commission is as follows: Gari Melchers, chairman; Frank Jewett Mather, jr., vice chairman; William H. Holmes, secretary; Herbert Adams, W. K. Bixby, James E. Fraser, Daniel Chester French, Joseph H. Gest, John E. Lodge, Charles Moore, James Parmelee, A. Kingsley Porter, Herbert L. Pratt, Edward W. Redfield, and Edmund C. Tarbell.

The executive committee is composed of Messrs. Moore, chairman, Gest, Holmes, Mather, jr., Parmelee, and Walcott; and the advisory committee is composed of Messrs. Redfield, chairman, Holmes, secretary, Adams, Melchers, Platt, Volk, and Miss Mechlin.

Subcommittees are as follows:

Committee on architecture, A. Kingsley Porter, chairman.
Committee on ancient European paintings, Frank J. Mather, jr., chairman.
Committee on prints, excepting the oriental, James Parmelee, chairman.
Committee on sculpture, Herbert Adams, chairman.
Committee on American paintings, E. W. Redfield, chairman.
Committee on ceramics, Joseph H. Gest, chairman.
Committee on oriental art, John E. Lodge, chairman.
Committee on modern European paintings, Gari Melchers, chairman.
Committee on textiles, no chairman at present.

The personnel of special committees is as follows:

On National Portrait Gallery, Herbert L. Pratt, chairman.
On gallery building, Charles Moore, chairman.
On raising fund for preliminary building plans, James Parmelee, chairman, Charles Moore, Charles D. Walcott.
On selection of architect for preliminary plans, Henry White, chairman, Herbert Adams, Frederic A. Delano, J. H. Gest, Gari Melchers, Charles D. Walcott, ex officio.
On department of architecture, ——— ———.
On preservation of architectural gems, ——— ———.

ACTIVITIES OF THE AMERICAN FEDERATION OF ARTS AND THE FEDERATION OF WOMEN'S CLUBS

The work of the American Federation of Arts, in promoting the development of the national gallery, deserves appreciative mention. At its 1923 convention in St. Louis the following resolution was unanimously adopted:

Whereas the United States is the only civilized nation which has no national gallery of art; and whereas there is great need for a building to house our

national art collection which in the past few years has greatly increased in size and value through gifts and bequests of public-spirited collectors and individuals; and whereas, on account of the lack of space in which to exhibit such gifts, this channel of beneficence is now checked; Be it

Resolved, That the American Federation of Arts undertake a campaign of education and promotion throughout the United States, in order to acquaint the people of existing conditions, in the hope that it may be their will when the facts are known, that a sufficient sum be appropriated by Congress to erect a suitable building at the National Capital to house the national collections and to evidence to the world that we, as a people, recognize art to be a factor in our national life.

Miss Leila Mechlin, secretary of the American Federation of Arts, states that the federation has at present 375 chapters or affiliated organizations in all parts of the United States. The intention of the federation is to secure the cooperation of these organizations, and to interest a membership numbering several hundred thousand individuals in the gallery movement.

Of like importance in the promotion of the national gallery are the activities of the Federation of Women's Clubs under the energetic direction of Mrs. Rose V. S. Berry, chairman of the art department of the federation. This great organization, whose activities extend to every State in the Union, seeks as one of its primary responsibilities to promote the cause of art, and especially to further art education in the most comprehensive manner. It seeks to have the world realize that the place given the arts of taste in a nation is an infallible test of the place that nation holds in the scale of civilization; it maintains that the promotion of these arts is thus a national responsibility. In its lecture courses and publications it utilizes the national collections, taking occasion to lay stress upon the humiliating fact that the American nation makes no adequate provision for the acquirement, care, and utilization of collections illustrating the world's achievements in the many branches of art, ignoring the example of all other civilized nations.

SPECIAL EXHIBITIONS HELD IN THE GALLERY

An exhibit of exceptional interest held in the middle room of the gallery March 3 to April 13 comprised 19 miniatures by Mr. Alyn Williams and 34 works of sculpture by Mr. Cecil Thomas, both exhibitors being Englishmen, although Mr. Williams spends much of his time in the United States. The exhibitors very generously prepared and had printed at their own expense a catalogue of the exhibits, copies of which were freely distributed. During the exhibit and for a short period thereafter Mr. Thomas was permitted to occupy one of the gallery spare rooms as a studio where he modeled two figure groups, The Duet and The Spirit of the Dance, the inspiration for which had come to him while in Washington. While

thus engaged Mr. Thomas was fortunate in having sittings for a portrait bust by Sir Esme Howard, British ambassador to the United States. This work met with gratifying approval and a replica in plaster was presented by the sculptor to the Smithsonian Institution at a dinner given in honor of Sir Esme by the Washington Branch of the English-Speaking Union, on May 13. Presentation was made by the presiding officer of the occasion, and it was accepted by Doctor Walcott, Secretary of the Smithsonian Institution, with appropriate words of appreciation.

A collection of portraits in oil and various studies in other techniques by Leo Katz of Vienna, Austria, was shown in the two north rooms of the gallery January 10 to February 15, and the exhibit, comprising 35 items, proved of very special interest to the people of Washington.

The gallery was fortunate in being permitted to place on view from December 16 to February 15 a collection of art works in bronze and terra cotta, nine in number, mainly busts of important personages, by Mrs. Nancy Cox-McCormack. These were mounted on appropriate pedestals in the south room of the gallery and included busts of Benito Mussolini, Italian premier, in black marble, and Henry P. Fletcher, ambassador to Italy, in bronze.

A collection of 72 water-color paintings of the scenery of the national parks of the Rocky Mountain and Pacific coast regions, by Gunnar Widforss, was exhibited in the middle room of the gallery December 10 to January 10. These paintings were vivid and highly realistic presentations of many remarkable subjects and attracted much favorable attention.

THE HENRY WARD RANGER FUND

As the paintings purchased during the year by the council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest are, under certain conditions, prospective additions to the national collection, the list, including the names of the institutions to which they have been assigned, is given here:

Title	Artist	Date of purchase	Assignment
42. The Other Shore	Robert Spencer, N. A.	Dec. 1, 1924	The Newark Museum Association, Newark, N. J.
43. Nancy	Lillian Wescott Hale	do	The Denver Art Museum, Denver Colo.
44. Their Son	Oscar E. Berninghaus	do	The Art Club of Erie, Erie, Pa.
45. The Wood Cart	Louis Paul Dessar, N. A.	Apr. —, 1925	
46. A Reading	Thomas W. Dewing, N. A.	do	
47. Dawn	Dwight W. Tryon, N. A.	do	
48. The Prodigal Son	Horatio N. Walker, N. A.	do	
49. Storm Birds	Armin Hansen	do	
50. Helen	Jerry Farnsworth	do	
51. Across the Valley	Hobart Nichols, N. A.	June 9, 1925	

The paintings purchased from the Ranger fund during the past fiscal year and unassigned at its close (1923–24) have subsequently been assigned as follows:

36. Midsummer, by William S. Robinson, N. A.; to the art gallery of Washburn College, Topeka, Kans.
37. The Bathers, by Spencer Nichols, A. N. A.; to the Art Hall of Beloit College, Beloit, Wis.
39. The Necklace, by Richard E. Miller, N. A.; to the Butler Art Institute, Youngstown, Ohio.
41. Clearing After September Gale—Maine Coast, by Howard Russell Butler, N. A.; to the Art Association of Indianapolis, Ind.

ART WORKS ADDED DURING THE YEAR

Permanent accessions of art works for the year are as follows:

Three paintings, the gift of Miss Emily Tuckerman: Hindoo Merchants, by Edwin Lord Weeks; Landscape (on copper), by Herman Saftleven; and The Refectory, by Eduardo Zamaçois.

Portrait of the late Hon. James R. Mann, member of the Board of Regents of the Institution from 1906 to 1911, by Gari Melchers. Gift of Mrs. James R. Mann.

Entrance portal to the Benjamin H. Warder house, 1515 K Street NW., Washington, D. C., designed by the eminent architect, Henry Hobson Richardson (1838–1886), including the door, carved trim and coussoirs (Berea grit). Gift of the cooperating committee on architecture in the National Gallery of Art, through Mr. Horace W. Peaslee, acting chairman, and 13 subscribers.

A landscape in water color, The Patriarchs, Zion National Park, by Gunnar Widforss. Gift of the artist.

Portrait of Chauncey Mitchell Depew, by George Burroughs Torrey. Gift of the Hon. Chauncey M. Depew, for the National Portrait Gallery.

Portrait bust in plaster (bronzed) of the Rt. Hon. Sir Esme William Howard, British ambassador to the United States, by Cecil Thomas. Presented by Mr. Cecil Thomas through the Washington branch of the English-Speaking Union.

The Libyan Sibyl, a statue in Carrara marble, heroic in size, by William Wetmore Story, and a portrait bust of Napoleon Bonaparte, in Carrara marble, by Raimondo Trentanove. Presented by the estate of Henry Cabot Lodge, through Mr. John E. Lodge.

Portrait of Dr. Samuel Pierpont Langley, by Mme. M. de Leftwich-Dodge. Gift to the Smithsonian Institution from Mme. A. Langley Ciocca, of Rome, Italy, sister of Doctor Langley.

Medallion portrait (in plaster) of Dr. Charles W. Eliot, president emeritus of Harvard University, by W. Clark Noble. Gift of Mr. W. Clark Noble.

Collection of French and other art objects, including silverware, furniture, porcelains, pottery, glassware, bronzes, etc. Bequest of the Rev. Alfred Duane Pell, D. D., not as yet fully received and recorded by the gallery.

LOANS ACCEPTED BY THE GALLERY

Portrait bust in marble of the late Samuel Gompers, president of the American Federation of Labor, by Moses Wainer Dykaar; lent by the American Federation of Labor.

Four paintings lent by the estate of Henry Cabot Lodge, through Mr. John E. Lodge, as follows: Portrait of Alexander Hamilton, by John Trumbull; portrait of Fisher Ames, by Gilbert Stuart; River Landscape with Cattle, by Constant Troyon; and Stable Interior with Horses and Groom, by John F. Herring.

A painting of large size, The Annunciation, attributed to Lorenzo Sabbatini (or Lorenzino da Bologna), lent by the Misses McKey through Miss Laura M. McKey.

LOANS BY THE GALLERY

Paintings belonging to the gallery were lent for exhibition elsewhere, as follows:

The large painting entitled "The Happy Mother," by Max Bohm, lent to the Painters and Sculptors Association, Grand Central Art Galleries, to be included in an important memorial exhibition of the works of this artist in November, 1924. Returned to its place in the gallery at the close of the exhibition.

The painting entitled "June," by John W. Alexander, lent to the American Federation of Arts for a special "Alexander exhibit." The collection was shown at Albany, N. Y., in the art department of the State Teachers College, and later at Easton, Pa., where it was used by the art supervisor of the Easton school district. The painting has been returned to its place in the gallery.

The three paintings, Birch Clad Hills, by Ben Foster, A Family of Birches, by Willard Metcalf, and The Island, by Edward W. Redfield, lent to the American Federation of Arts for the International Exhibition of Paintings by American Artists held in Venice, Italy, during the summer of 1924, have been returned to the gallery.

One set of colored slides of works belonging to the gallery, lent to the American Federation of Arts, and a second set to the art department of the American Federation of Women's Clubs, are retained for utilization by these organizations. In several instances selections from the gallery's collection of slides have been lent to the normal schools of Washington and to the art department of Howard University.

DISTRIBUTIONS

Paintings lent to the gallery have been withdrawn by their owners during the year as follows:

Rosita, by I. Zuloaga; withdrawn by the Hon. John Cecil for Mrs. George W. Vanderbilt.

Portrait of His Daughter, by Titian (copy?); withdrawn by Mr. Joseph Stewart, who had purchased it from the former owner, Dr. Nathan Boyd.

Self Portrait by James Deveaux; withdrawn by Dr. Houston Mifflin, the owner, who had deposited it in the gallery through Dr. Porter F. Cope.

The Pickering Dodge Collection of seven cameos; withdrawn by Mrs. Charles W. Rae.

Portrait of Chief Justice Joseph C. Hornblower and portrait of Mary B., his wife, artist unknown; portrait of Roderick Austin, attributed to Sir Godfrey Kneller; and a painting representing a sacrifice interrupted by soldiers, artist unknown; withdrawn by Mrs. Caroline B. Hornblower.

Klingle Ford, by Max Weyl; withdrawn by Mrs. John W. Smith.

PUBLICATIONS

Holmes, W. H. Report on the National Gallery of Art for the year ending June 30, 1923. Appendix 2, Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1923, pp. 45–58.

——— Report on the National Gallery of Art for the year ending June 30, 1924. Appendix 2, Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1924, pp. 48–58.

Catalogue of a collection of water-color paintings of the Grand Canyon of the Colorado, Yellowstone National Park, Yosemite Valley, Zion National Park, Utah National Park, and the Monterey Coast of California. Of special interest to the Interior and Agriculture Departments. By Mr. Gunnar Widforss. On view in the central room of the National Gallery, Natural History Building, United States National Museum, December 10 to January 10. Washington, 1924, pp. 1–4.

Catalogue of a collection of busts of prominent personages in bronze and terra cotta, by Mrs. Nancy Cox-McCormack, on view in the south room of the National Gallery, Natural History Building, United States National Museum, December 16, 1924, to January 16, 1925. 1924, pp. 1–4.

Catalogue of a collection of portraits and studies in different techniques, by Leo Katz, of Vienna, Austria, on view in the north rooms of the National Gallery, Natural History Building, United States National Museum, January 16 to February 15, 1925. 1925, pp. 1–4.

Catalogue of recent miniature portraits by Alyn Williams, P. R. M. S. (President, Royal Miniature Society), and portrait busts in bronze and plaster, relief portraits, medallions, carvings in precious and semiprecious stones, and some great seals, by Cecil Thomas, R. M. S., on view in the National Gallery, Natural History Building, United States National Museum, March 3 to March 22, 1925. 1925, pp. 1–8.

Respectfully submitted.

W. H. Holmes,
Director.

Dr. Charles W. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 3

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the fifth annual report on the Freer Gallery of Art for the year ending June 30, 1925:

THE COLLECTION

Work has been continued during the year in the preservation of the collection, and in the print collection a total of 1,056 objects have now been put in final condition. A complete list of the Freer Gallery collection of paintings, pastels, drawings, prints, and copper plates by and attributed to American and European artists, together with a list of original Whistleriana, has been prepared and is about to be published in pamphlet form. This pamphlet will be placed on sale with the other publications issued by the gallery.

Changes in exhibition during the year involved 46 oil paintings, 2 water colors, 12 pastels, 30 etchings and dry points, 38 lithographs, 2 Japanese screens, 3 Japanese panels, 1 Japanese *makimono*, 4 Chinese panels, 2 Chinese scrolls, 11 Chinese bronzes, 1 Indian bronze, and 2 Chinese textiles.

Additions to the collections have been as follows:

By gift of Charles A. Platt:

AMERICAN PASTEL

25.1. Whistler, James McNeill; portrait of Miss Emily Tuckerman.

By purchase:

INDIAN BRONZE

24.10. Buddhist statuette: Saṁvara (*Yi-dam*, tutelary divinity). Nepal, fifteenth century.

INDIAN PAINTING

24.4. *Laila Majnun.* Mughal, time of Jahāngir (1606–1628).
24.5. Ādil Shāh. Mughal, time of Jahāngīr (1606–1628).
24.6. Fireworks. Illuminated manuscript on the reverse. Mughal-Rajput, time of Shāh Jahān (1628–1658). By Muhammad Afzal.
24.7. Mālaśrī Rāginī (a musical mode). Rajput, about 1600.
24.8. Bhairavī Rāginī (a musical mode). Rajput, about 1675.
24.9. A visit to a temple. Rajput-Mughal, about 1675.

CHINESE BRONZE

25.2. Ceremonial vessel of the type *tsun.* Early Chou dynasty (1122 to 255 B. C.).
25.3. Ceremonial wine vessel of the type *chio.* Chou dynasty (1122 to 255 B. C.).

CHINESE PAINTING

24.3. Landscape: Breaking waves and autumn winds. A scroll. By Tai Chin. Ming, middle fifteenth century.

NEAR EASTERN POTTERY

25.4. Bowl with painted decoration. Persian Rhages. Twelfth-thirteenth century.
25.5. Bowl with painted decoration. Persian, Rhages. Twelfth-thirteenth century.
25.6. Bowl with decoration in gold luster. Persian. Eighth century.
25.7. A small dish with painted decoration under glaze. Arab. Tenth-eleventh century.
25.8 Bowl with engraved decoration, under glaze. Persian. Ninth century.
25.9. Bowl with decoration engraved and painted under glaze. Persian. Ninth century.
25.10. Bowl with decoration engraved and painted under glaze. Persian. Ninth century.
25.11. Bowl with decoration engraved and painted under glaze. Persian. Ninth century.
25.12. Bowl with decoration painted in black over glaze. Persian. Ninth century.

Additions to the library by gift and purchase comprise 90 books and periodicals and 127 pamphlets. A list of these accompanies this report as Appendix A (not printed). Forty-six volumes have been rebound.

The work of making identification photographs for use in the card catalogue continues, and in addition, several hundred photographs and a number of lantern slides have been made to order and delivered to purchasers. Of the publications issued by the gallery, there have been sold during the year, 538 copies of gallery books, 422 copies of the Synopsis of History, and 682 copies of the descriptive pamphlet.

During the past year there has been an increasing demand upon the gallery for translations of Chinese, Japanese, and Tibetan inscriptions, and for information concerning various objects. One hundred and five such objects, consisting, for the most part, of Chinese, Tibetan, Japanese, and Korean paintings, Japanese prints,, and articles of pottery and jade, have been submitted for examination.

The usual work in repairing and making exhibition cases, picture frames, stretchers, and other equipment has been done in the gallery shop, and the necessary minor repairs to the building, as well as certain improvements such as the construction of a photographic dark room in the attic, were made by the employees of the shop.

The Freer Gallery begs to acknowledge its indebtedness to the Department of Agriculture for its aid in exterminating the boxwood pest, "the leaf miner," and to thank the Fish Commission for its gift of goldfish for the fountain basin.

ATTENDANCE

The gallery has been open every day, with the exception of Mondays, from 9 until 4.30. The total attendance for the year was 109,862. The aggregate Sunday attendance was 28,172, making an average of 541; the week-day attendance amounted to 81,690, with an average of 313. Of these visitors, 431 came to the study rooms to see objects not on exhibition or to consult books in the library; 4 to make copies or photographs, 72 to examine the building and equipment, while 27 brought objects in their possession for examination and information.

PERSONNEL

Mr. Y. Kinoshita, of the Museum of Fine Arts, Boston, worked at the gallery during the winter months on the preservation of oriental paintings.

Mr. Herbert E. Thompson worked on the preservation of oil paintings.

FIELD WORK

A detailed account of the activities of the gallery's expedition in China is contained in Appendix B (not printed) accompanying this report, and will be condensed for publication in Explorations and Field Work of the Smithsonian Institution in 1925.

Respectfully submitted.

J. E. Lodge, *Curator.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the researches, office work, ond other activities of the Bureau of American Ethnology during the fiscal year ended June 30, 1925, conducted in accordance with the act of Congress approved June 7, 1924. The act referred to contains the following item:

American ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archeologic remains, under the direction of the Smithsonian Institution, including the necessary employees and the purchase of necessary books and periodicals, $57,160.

The policy of the Bureau of American Ethnology in the past has been that of a pioneer, but from necessity the field work of the staff has been both intensive and extensive, mainly reconnaissance. As a pioneer, the bureau has opened up new lines of research in the study of the ethnology of the American Indians and has blazed a trail for others in several fields. While contributing to science technical monographs on certain Indian tribes, it has at the same time prepared and circulated, through publication, articles of a popular character covering the whole subject. The object has been to furnish reliable data for students wishing accurate knowledge of the American Indians.

The aboriginal culture of our Indians is rapidly disappearing and being replaced by the white man's civilization. Certain tribes have already lost almost all their native customs, and others will follow rapidly until little of scientific value remains for ethnological field work. The older men among them, who in their prime knew the native cults and rituals, are passing away, and the younger generation of Indians who are taking their places are almost entirely ignorant of the significance of the rituals or ceremonials. Current fables and metaphoric stories, mainly explaining the characteristics of animals, are now often claimed to be mythologic, although many of them have value as tales, not as myths. The Indian culture is passing away and soon will be lost. It is the intention of the Bureau of American Ethnology to record it before its extinction.

The excavation and preservation of archeologic remains, from which much valuable scientific material may be obtained, constitute

a task which is only just begun. The bureau has for many years been a pioneer in this work, and in many areas it has been the only investigator. The first publication of the Smithsonian Institution was on an archeological subject, and with the passing years the bureau has followed this line of work with vigor.

It is a traditional, sound policy of the Institution, as a result of the relatively small allowance for the field study of the Indians, to cooperate, rather than to attempt to compete with those who have a much larger income. This policy has been pursued by the bureau during the past year.

The chronicles of De Soto's wonderful trip through our southeastern States introduced to the attention of historians a remarkable aboriginal American culture, one of the most advanced in North America outside of Mexico. It was, as has generally been the case, built on agriculture, and the dominant tribal religion of its civilization was a complex of Sun, Fire, and Great Serpent cults. From Tampa Bay to the Mississippi River, De Soto encountered numerous tribes differing in language and in minor ethnological features, but all belonging to the same culture with a worship characteristic wherever agriculture served as a source of food. As time went by and renewed exploration brought Europeans into more intimate contact with the Indians of the Gulf States, historians and others published many articles on their ethnology, but as the tribes were moved west of the Mississippi and the opportunities for the field worker were diminished, the time came for the ethnologist to yield to the archeologist to make his contribution to the subject. Here lies a great field for further studies, with ample work for both the historian and the archeologist.

The two areas in aboriginal America north of Mexico in which agriculture reached its highest development were the Southwest, or that part of our domain bordering on Old Mexico, and those States bordering on the Gulf of Mexico, including the mound builders from the Ohio River to the Gulf. The investigation of the southwestern or pueblo region is at present attracting many archeologists amply furnished with funds, but the Southeastern or Gulf States have been more or less overlooked. The bureau has begun an archeological reconnaissance, as far as its resources will allow, in Florida, Mississippi, Alabama, and Tennessee. Last year special attention was given to the Indian mounds at Muscle Shoals in Alabama. The work in Tennessee, southern Florida, and Mississippi, so auspiciously begun by the late Mr. W. E. Myer, has been continued by Mr. P. E. Cox, State archeologist of Tennessee. Mr. Collins, assistant curator, division of ethnology, United States National Museum, was allotted a small appropriation for preliminary

investigations and reconnaissance along the Pearl River in Mississippi, the prehistoric home of the Choctaw Tribe. The results of this work were very satisfactory.

Work on the Muskhogean culture, or the antiquities of the Gulf States, promises important results in comparative ways, and will, it is hoped, shed light on the religion of aboriginal tribes of North America. We are able to reconstruct, in a way, from historical sources, the main outlines of the Gulf culture, but the documentary references to the material culture of the Muskhogean tribes are incomplete. More information is needed regarding the ritualistic sacra, idols, ceremonial objects, and symbolism on pottery, before we can reconstruct the cultus. The material for this study is now buried in the soil, but intensive archeological work will bring it to light. In essentials, the culture of the prehistoric people of the Gulf States is such as we find universal among agricultural people in America emerging from savagery into barbarism, and the religion has much in common with that of the pueblos.

SYSTEMATIC RESEARCHES

The chief spent several weeks in reconnaissance near Florence, Ala., making excursions to several mounds in that vicinity, especially those that will be submerged when the Wilson Dam at Muscle Shoals is flooded. Mr. Gerard Fowke, who had immediate charge of the excavations in two of these mounds, obtained a considerable collection containing unique objects, among which are three rare copper ornaments, the largest ever found in the valley of the Tennessee. His report will be published later.

The chief at that time visited Montgomery, Ala., where he was most hospitably received. While there he made an examination of the Graves collection, one of the most remarkable in the State.

The chief has given advice to the National Park Service of the Interior Department on the new National Monument near Flagstaff, Ariz., which is now called by the Hopi name Wupatki. This monument includes the well-preserved buildings near Black Falls on the Little Colorado, first described and figured by the writer a quarter of a century ago, at which time he recommended that they be made a National Monument, and this has now been done by proclamation of the President.

The most important collection of archeolgical objects received during the past year was contributed by Mr. J. C. Clarke, of Flagstaff, Ariz., custodian of the Wupatki ruin. It consists of about a hundred specimens of pottery, shell and bone implements, and other artifacts from a burial mound at Youngs Canyon excavated by workmen in the course of construction of a road near the city. These

objects were received at a time when material from that region of the Southwest was particularly desirable. The chief has prepared an illustrated report on this collection in which he calls attention to its importance. The collection contains unique specimens and is accompanied by a good catalogue by Mr. Clarke. One of the most interesting of these is a black and white pottery ladle, the handle of which is molded into a cradle containing a clay figure. There is also a finely incised head-ornament of bone, recalling those worn by the Bow priesthood at Zuñi, and suggesting similar ornaments of the Hopi idol of the war god. The collection shows evidence of cremation and urn burial.

The pottery objects are archaic, and the interiors of certain black-and-white food bowls are decorated with artistic figures similar to those on polychrome ware from Tokonabi, near March Pass, in northern Arizona. It is probable from the pottery that the people who buried their dead at Youngs Canyon were related to a population antedating pueblos, which was scattered over a great area in Arizona from the Little Colorado north to the San Juan, and from the western boundary of the state into New Mexico. This people had no circular kivas or ceremonial rooms like those at the Mesa Verde, or the San Juan area, but they were fine potters who decorated their ware with artistic geometrical designs.

The number of written requests for information on ethnological subjects the last few years has more than doubled, and the time of the chief, as well as of the members of the staff, is correspondingly absorbed.

During the past year Mr. Earl H. Morris, under the direction of the chief of the bureau, did necessary repair work on the famous tower of the Mummy Cave House in the Canyon del Muerto, Arizona, which once contained three rooms. All woodwork on the first ceiling has been torn out; only the haggled ends of a few supports remain embedded in the walls. The cleanly peeled poles which supported the second ceiling are in place, and the third ceiling, or original roof, is still intact. It is probably the most beautiful ceiling remaining in any ruin in the Southwest, its only rivals being the coverings of one or two rooms in the north side of Pueblo Bonito, and in Spruce Tree House, Mesa Verde.

This tower has been in a dangerous condition for a long time. There was originally a retaining wall below it, rising from the very brink of the ledge, which held in place the fill of loose rock and refuse upon which the House of the Tower stands. Eventually, through erosion, all but the eastern end of this wall collapsed, probably because of the insecure foundation afforded by the abruptly sloping rock, and much of the material behind it washed over the

cliff. Later, the not infrequent winds which sweep over the cave with unbelievable force, blew out the dust and rock pebbles until the southwest corner of the tower was undermined more than 3 feet and the wall eastward weakened almost to the opposite corner.

The cracks in the west wall were wider in November, 1924, than they were a year previous. A removal of half a dozen shovelfuls from the unconsolidated mass of earth beneath the front would have loosened the large block just beyond its western end, which prevented the entire collapse of the masonry. In addition to the periodic action of the wind, each visitor who passed from the eastern to the western part of the cave trod his portion of the loose mass below the wall farther down the slope, and sent clods and pebbles rattling over the cliff. Before many years this block would have been loosened and the tower would have fallen.

During the repair work, buttresses were built beneath and inclosing the large blocks under the west end of the tower and under the undermined portion of the tower, continuing back to the limit of undermining, and extending well forward of the masonry. At the junction of the two, wedges were driven to knit the new work firmly to the old. From the east end of the buttress a retaining wall was built to connect with the remnant of the old one on the brink of the ledge, and the space behind it was filled, thus providing a platform instead of the former steep slope at the southeast corner of the tower. This repair work will temporarily preserve one of the finest gems of aboriginal architecture in the entire Southwest, but it should be supplemented by the addition of "turnbuckles" anchored to the cliff and by the rebuilding of the southeast corner, which should be bonded to the east and front wall to preserve it for centuries to come.

During the fiscal year Dr. John R. Swanton, ethnologist, discovered further material bearing on the social and religious life of the Creek Indians, and this was extracted and incorporated into his papers on those subjects which are now being prepared for publication by the editor. A study also was made of the various smaller culture centers within the region covered by our present Gulf States, and a paper on the "Culture of the Southeast" was prepared as a result of this work. A short paper on the "Ethnology of the Chickasaw" was begun and carried nearly to completion, and the work of carding references to all words from the publications of early Florida missionaries in the now extinct Timucua language has been continued, and all of the words from three of the five texts and from more than half of the fourth had been extracted by the end of the year. An abbreviated handbook of the Indian tribes in the United States and Alaska was prepared to accompany a map of the same section.

Dr. Truman Michelson, ethnologist, prepared for publication a manuscript entitled 'A Sauk and Fox Sacred Pack." He also wrote the Indian text of one of the great sacred packs of the Thunder gens of the Fox Indians and worked out the English version thereof. Doctor Michelson also prepared an Indian text, with English version, of the Owl dance which belongs to the Bear gens. He began translating a Fox text on the sacred pack named "Sakimage" which belongs to the Bear gens of the Fox Indians and which was taken care of by Pushetonequa, the last chief recognized by the Government. He corrected the galley proofs and the first page proofs of the fortieth annual report of the bureau, which made it possible to incorporate some additional material appurtenant to the White Buffalo Dance and Fox mortuary customs and beliefs. Doctor Michelson employed Horace Powesheik to translate 1,000 pages of Fox text which contains additional information on the Fox society known as "Those Who Worship the Little Spotted Buffalo." In June Doctor Michelson went to Tama, Iowa, to renew his researches among the Algonquian Tribe of that State. He verified the new data on the Fox society named above, and some Fox texts on the Buffalo Head Dance of the Thunder gens, obtaining much additional information of this dance and other information on the Thunder gens. A translation of the Fox text on the Sturgeon was obtained as well as certain information on the Wolf gens.

During the fiscal year Mr. John P. Harrington, ethnologist, was engaged in the preparation for publication of his material on the excavation and early history of the Burton Mound Indian village situated at Santa Barbara, Calif., the principal rancheria of the Santa Barbara Indians. The Ambassador Hotel, which had stood on the mound for many years, and had completely barred it to scientific investigation, was destroyed by fire in the spring of 1921. By joint arrangement with the Museum of the American Indian, a thorough excavation of this mound was made, and a large and attractive collection of artifacts was obtained, as well as a mass of archeological and historical material. Mr. Harrington completed the elaboration of this material and it was submitted for publication, including maps and numerous photographs.

The old Indian name for the Burton Mound village was Syujtun. Mr. Harrington's work revealed the interesting fact, not previously pointed out, that this rancheria is mentioned four times in the "Relacion" of Juan Rodriguez Cabrillo, who discovered Alta California in 1542. Father Crespi, who kept the diary of the Portola expedition, writing in 1769, describes this village in some detail. Other early accounts tell that Yanonalit, its chief, had under him 12 other villages besides the Burton Mound. After the Indian popu-

lation was removed to the near-by Santa Barbara Mission, which was accomplished gradually after the establishment of the mission in 1782, the Franciscans erected a massive adobe warehouse on the mound, the old Indian canoe landing place in front of the mound having become "el puerto de Santa Barbara," the port of Santa Barbara. Ships visiting Santa Barbara used to get water from the large spring on the southern slope of the mound. Joseph Chapman, a young Englishman who had been captured when pirates made a raid on the California coast, purchased the mound from the Franciscans in the early twenties and started a flour mill there. In the forties the mound became the property of George Nidiver, famous otter hunter and friend of General Fremont. In the sixties the mound property was owned by Lewis T. Burton, whose name it still bears. The hotel was erected on the site in 1901. The shape and extent of the Indian village and graveyards was laboriously worked out by excavation and successive cultures traced, for the site proved to be very ancient.

In the cemetery plots, most of the bodies were buried in hunched-up positions with the head to the north, that is, in the direction of the mountain range. Many of the graves had been lined with whalebone slabs, some fine specimens of which were obtained. A great variety of belongings, large and small, had been stowed away with the bodies, and traces of matting, basketry, and wooden utensils indicated that the archeologist had been deprived of the richest treasures through decomposition in the ground. One complete wooden awl for basketry, such as is described by the early fathers, was recovered. Several of the graves contained caches of large and beautifully finished steatite bowls; these were manufactured at the steatite quarries on Santa Catalina Island and were brought up the channel for barter in Indian canoes. Screening the earth brought a surprising variety of shell and glass beads. The shell beads have been sorted and classified, and the kind of native shell used for each variety has been determined.

In 1924 the Burton Mound property was sold and subdivided. Extensive grading of the property for new streets and trenching for pipe lines of various kinds was carefully watched and reported on by Prof. D. B. Rogers, who has cooperated with Mr. Harrington in this work, and yielded new information about the stratification of the mound and a good sized additional collection of artifacts. A new hotel with large cellar excavations is about to be built on the crest of the mound and observation of these operations will doubtless add still further data to that already presented in the report.

On completing the Burton Mound paper, Mr. Harrington prepared a report on the archeology of the Santa Barbara region, dealing with

the sites adjacent to the Burton Mound along both historical and archeological lines. This is a virgin field of research and has already yielded important contributions to our knowledge of the culture sequences of the ancient California Indians of this region, which had the most specialized and highly developed culture of the State.

This work illumines the fact that the early population of the channel was dense and that there were numerous wars and tribal shiftings. The section of the coast from which the islands were populated and the comparative ages of rancheria sites are also apparent from this work.

In October, 1924, Mr. R. O. Marsh brought to Washington a party of eight Tulé Indians from Panama, who remained in the city until January, 1925. This afforded opportunity for studying the language, which is a peculiarly interesting one. Possessing only 18 letters and employing them both short and long, it sounds to the ear more like Finnish than like the average American Indian language. The language may be described as melodious, simple and flexible in structure, yet very rich and extensive in vocabulary. It is spoken, with slight dialectic differences only, by a very large body of Indians, who formerly held a strip of Caribbean coast more than 240 miles long between the Canal Zone and the south of the Rio Atrato, together with the numerous fertile keys off the coast. Lists were obtained of sociological terms, names of places, plants and animals, and designations of material culture objects. Songs and speech were recorded on the dictaphone.

The Indians have been called Tulés, Cunas, Comogres, and San Blasenos. Of these names the first is preferable because it is the native name of the tribe. The word Tulé means merely "Indian," it being understood that it refers to Indians of that peculiar kind and language. It is related to the word tula, meaning 20, that is, all fingers and toes, an entire Indian.

The collection of Tulé ethnological objects donated by Mr. Marsh to the National Museum was examined with the Indian informants and the native names of the objects were recorded, together with information about their use.

The best informant in the party was Chief Igwa, who is "captain" over some 10 keys, and is one of the leading men in the councils of the tribe. He has traveled much about the Tulé country and knows hundreds of places by name, being a good ethnogeographical informant. The chief prepared a large map showing these places.

Mr. J. N. B. Hewitt, ethnologist, left Washington in May, 1925, for Brantford, Canada, to resume his researches among the Six (originally Five) Nations, or Tribes, of the Iroquois, the Mohawk, the Seneca, the Onondaga, the Oneida, the Cayuga, and the Tus-

carora, and also among the Munsee of the Delaware Algonquian group of languages who dwell on the Haldimand grant on the Grand River in Ontario, Canada.

Here Mr. Hewitt took up the literary interpretation, revision, and textual criticism of previously recorded voluminous Iroquoian texts relating to the Constitution of the League or Confederation of the Iroquois tribes, embodying its laws and ordinances and the rituals of the council of condolence for the deceased, and the installation of new members of the Federal and the tribal councils.

With the aid of the two best Mohawk informants available who still retain some definite knowledge of portions of the ancient institutions of the league of the Iroquois, Mr. Hewitt made a free English translation of an important one of these rituals, in addition to the free rendering of the chant of "The seven songs of farewell," and thereby recovered the symbolic reason for the very peculiar name of the former. This ritual is called Kā'rhawĕⁿ'hrā'toⁿ', in Mohawk, and Gā'hawĕⁿ'hä'di', in Onondaga, meaning, "Cast or thrown over the grand forest." When used ceremonially both these chants are separated into two portions, and the four portions alternate in their rendition in such manner that part one of the one chant is followed by part one of the other; and part two of the first is followed by part two of the second chant. But when chanted "a veil of skins" (shawls or blankets serve in modern times) must be hung across the place of assembly in such wise as to divide the mourning from the other side of the league.

Ceremonial or legislative action by the tribe or by the league is taken only through the orderly cooperation of two sisterhoods of clans for the former, or of two sisterhoods of tribes for the latter. This dualism in the highest organic units of organization was originally based on definite mythic concepts. In either organization one sisterhood represented the female principle or the motherhood in nature, and the other sisterhood the male principle, or the fatherhood in nature. This dualism is thought to be so important that the language of the rituals and of official courtesy employ terms embodying the ethnic and mythic significance of it.

By a searching study of all symbolic terms and phrases occurring in the chants of these rituals, which impliedly might refer to the highest dramatized situation revealed by these two divided chants, the parts of which are recombined as described above, Mr. Hewitt was able to identify beyond all reasonable question the phrase "the veil of skins" with the other phrase "the grand forest." The "grand forest" represents ritualistically the totality of the forests which intervene between the lands of the mourning side of the league and those of the other side, represented as symbolically intact in

mind. It must not be overlooked that either the mother side or the father side may be the "mourning side"; the designation, of course, alternates between the two sides, depending on the fact of the loss of one or more of the members of the Federal council belonging to it at any given time.

The sisterhood of tribes functioned by the independent action of its constituent institutional units—every several tribe. In turn every tribe functioned through the organic units of its own internal organization—each several clan, to execute its prescribed part in the larger Federal action, which otherwise would not be authentic or authoritative; so that a clan or an individual in a clan, in special cases involving personal rights, might prevent vital Federal action. So personal rights were abundantly safeguarded.

Mr. Hewitt purchased a very fine specimen husk mask of the Corn Mother, with a short explanatory text.

Mr. Hewitt also made a reconnaissance trip to the Chippewa of Garden River, Canada, for the purpose of expanding and deepening his knowledge of certain Chippewa texts, recorded in 1921 by him from the dictation of Mr. George Gabaoosa, of Garden River, and also to obtain data in regard to the derivation of two very important proper names, Chippewa and Nanabozho (appearing in literature also as Nenabojo, Menaboju, and Wenaboju), and also to inform himself as to the ethnologic value to be placed on the fast-fading remains of the ethnic culture of this and cognate tribes in like situations and antecedents. The myth of Mudjikewis, "The First-Born (on Earth)," commonly called the story of Nanabozho (i. e., *Inābi'oji'o'*), remarkable for beauty and comprehensiveness, details the circumstances which gave rise to the name "Nanabozho." In that recital the name appeared as *Inābi'oji'o'*) and means "Created, or formed, by the look (of the Great Father spirit)."

The name Chippewa appears in literature in no less than 97 variant spellings, with a half dozen or more unsatisfactory definitions. But to those who first gave the name Chippewa (in its native, not Europeanized, form) to these people, picture-writing was ethnically distinctive and characteristic of them as the well-known birch-bark records of these people amply testify. So the name Chippewa signifies literally, "Those who make pictographs," and thus emphasizes one of the distinctive arts of these peoples.

The Seneca in Missouri and Oklahoma were visited for the express purpose of identifying them tribally, if the available information made this possible. Since the middle of the eighteenth century these Seneca have not been closely affiliated with the Seneca Tribe of New York State and Canada. There has been expressed doubt that these western Seneca had the right to this name. But after

visiting and interviewing many families of these western Seneca dwelling about Seneca, Mo., and Miami and Picher, Okla., Mr. Hewitt was convinced that they are mainly emigrants from the parent Seneca Tribe of New York and Canada and from the Cayuga of these last-named places; naturally, there are also some families of other Iroquoian Tribes, such as the Wyandot and possibly the Conestoga. A porcupine clan and a fox clan were reported. The last was a Conestoga clan.

Mr. Francis La Flesche, ethnologist, completed his paper on two versions of the child-naming rite of the Osage Tribe. The first version belongs to the In-gthon-ga or Puma gens, and the second to the Tsi-zhu Wa-shta-ge or Tsi-zhu Peacemaker gens. Each gens has its own version of the rite and no other gens can use it without permission. This paper contains 201 typewritten pages and 20 illustrations. Mr. La Flesche spent a part of the month of May and all of June, 1925, among the Osages. In the early part of this visit he and his assistant, Ku-zhi-si-e, a full-blood Osage, undertook the laborious task of properly recording the gentile personal names used by the full-blood members of the tribe and by some of the mixed bloods. Superintendent J. George Wright, of the Osage Agency, kindly permitted them to use as a guide in doing this work an annuity pay roll of the third and fourth quarters of the year 1877, which was found in the files of his office. This roll contains about 1,900 Indian names, most of them misspelled. Besides correcting the spelling of the names, Mr. La Flesche and his assistant added to the name of each annuitant the name of his or her gens. Ku-zhi-si-e was much amused to learn that his boy name, "I-tse-tha-gthin-zhi," was carried on the pay roll as "E-stah-o-gra-she," and that the boy name of his friend "Wa-non-she-zhin-ga" was put on the rolls as "Me-pah-scah," instead of "In-bae-sca," the correct name.

When the work of revising the names on the annuity roll was concluded, Ku-zhi-si-e drove over the hills on his farm with Mr. La Flesche and showed him many wild plants which were useful to the Indians as medicine or food. Some of these plants were woven into large mats for house covering, and into rugs to spread on the floor of the house to sit upon.

Wo-non-she-zthin-ga (the chief of the tribe) also took tramps among the trees on his farm with Mr. La Flesche, and showed him a number of trees and explained to him their uses, and gave to him their native names, which he recorded. This man pointed out a tree which he called "Zhon-sa-gi," hard wood. The saplings of this tree he said were used for the frames of the houses. When green the wood was easily cut with a knife or ax, but when sea-

soned it was very hard to cut. The chief cut a branch from a small tree and carried it with him when he and Mr. La Flesche returned to the house. The chief whittled off some of the bark from the branch and dipped the shavings in a glass of water and the water quickly became blue like indigo. Mr. Paul C. Standley identified this tree as the blue ash, or *Fraxinus quadrangulata.*

SPECIAL RESEARCHES

The following manuscripts of Indian music have been purchased during the fiscal year from Miss Frances Densmore: "War, wedding, and social songs of the Makah Indians," "Songs connected with Makah feasts and dances," "Music and customs of the Tulé Indians of Panama," "Songs and instrumental music of the Tulé Indians of Panama," "Songs for children and material culture of the Makah Indians," and 17 mathematical groups analyses of 167 Papago songs, according to the method of such analyses in previous work. This material (apart from the group analyses) comprises 150 pages of text, numerous photographic illustrations, and the transcriptions of 69 songs, together with the original phonograph records and descriptive and tabulated analyses of individual songs. The last named are the analyses from which the mathematical analyses are made, these showing the peculiarities of the songs of an entire tribe with results expressed in percentages. These in turn form the basis for comparative tables, which show the characteristics of the music of different tribes. Such tables of comparison in "Mandan and Hidatsa Music" comprise 820 songs collected among six tribes, and material awaiting publication will add more than 500 songs to this number, including songs of widely separated tribes. It seems possible that these tables may show a connection between the physical environment of the Indians and the form assumed by their songs, as interesting contrasts appear in the songs of different tribes.

The final paper on the Makah Indians included a description of the uses of 26 plants in food, medicine, and dye. Specimens of the plants had been obtained on the reservation, and their botanical identification was made by Mr. Paul C. Standley, of the United States National Museum. The Makah were head hunters and a detailed account of their war customs was presented. The caste system prevailed in former days and families of the upper class had wealth and leisure. The wedding customs were marked by festivity and by physical contests, the songs of which were submitted.

The presence in Washington of a group of Tulé Indians from the Province of Colon, Panama, made possible a study of forms of primi-

tive music which, it is believed, have not hitherto been described. The Tulé Indians are unique in that they do not pound on a drum, a pole, or any other object. Their favorite musical instrument is the "pan pipe" of reeds. Two men usually play these pipes, sounding alternate tones. The music of these pan pipes was phonographically recorded and transcribed as nearly as is possible in musical notation. An instrument which, as far as known, has not been previously observed, is a reed flute having two finger holes but no "whistle opening." The upper end of the reed is held inside the mouth, possibly touching the roof of the mouth, and for this reason the instrument is designated as a "mouth flute." A gourd rattle, conch shell horn, and bone whistle complete the musical instruments of these Indians.

The words of the songs narrate a series of events, such as the preparation for a wedding and a description of the festivity, or the illness and death of a man, followed by "talking to his spirit." Chief Igwa Nigidibippi, who recorded the songs, was a trained singer.

EDITORIAL WORK AND PUBLICATIONS

The editing of the publications of the bureau was continued through the year by Mr. Stanley Searles, editor, assisted by Mrs. Frances Nichols, editorial assistant. The status of the publications is presented in the following summary.

PUBLICATIONS ISSUED

Thirty-eighth Annual Report. Accompanying paper: An Introductory Study of the Arts, Crafts, and Customs of the Guiana Indians, by Walter E. Roth. 745 pp., 183 pls., 341 figs.

Thirty-ninth Annual Report. Accompanying paper: The Osage Tribe; The Rite of Vigil, by Francis La Flesche. 636 pp., 17 pls., 4 figs. (Received July 13, 1925.)

Bulletin 78. Handbook of the Indians of California, by A. L. Kroeber. x, 995 pp., 83 pls., 78 figs. (Received July 17, 1925.)

PUBLICATIONS IN PRESS OR IN PREPARATION

Fortieth Annual Report. Accompanying papers: The Mythical Origin of the White Buffalo Dance of the Fox Indians; The Autobiography of a Fox Indian Woman; Notes on Fox Mortuary Customs and Beliefs; Notes on the Fox Society Known as "Those Who Worship the Little Spotted Buffalo"; The Traditional Origin of the Fox Society Known as "The Singing Around Rite" (Michelson).

Forty-first Annual Report. Accompanying papers: Coiled Basketry in British Columbia and Surrounding Region (Boas, assisted by Haeberlin, Roberts, and Teit); Two Prehistoric Villages in Middle Tennessee (Myer).

Forty-second Annual Report. Accompanying papers: Social Organization and Social Usages of the Indians of the Creek Confederacy; Religious Beliefs and Medical Practices of the Creek Indians; The Culture of the Southeast (Swanton).

DISTRIBUTION OF PUBLICATIONS

The distribution of the publications of the bureau has been continued under the immediate charge of Miss Helen Munroe, assisted by Miss Emma Powers. Publications were distributed as follows:

Report volumes and separates	3,426
Bulletins and separates	3,458
Contributions to North American ethnology	38
Introductions	5
Miscellaneous publications	427
	7,354

As compared with the fiscal year ended June 30, 1924, there was a decrease of 6,609 publications distributed. This was undoubtedly due not to a decrease in applications, but to the fact that only one publication was distributed during the year just ended, whereas four publications were issued in the preceding fiscal year and distributed to the mailing list.

ILLUSTRATIONS

Mr. DeLancey Gill, illustrator, with the assistance of Mr. Albert Sweeney, continued the preparation of the illustrations of the bureau. A summary of the work follows:

Illustrations mounted, retouched, and made ready for engraving	927
Drawing of objects, maps, etc., prepared	38
Portraits of visiting Indians (2 Kiowa, 8 Tulé)	27
Negative films from field exposures	54
Photostat prints from books and manuscripts	178
Negatives of ethnologic and archeologic subjects	273
Photographic prints for distribution and office use	1,649

On account of the large amount of illustrative work, reclassification of the large collection of negatives has not progressed as rapidly as last year. About 7,000 negatives have so far been catalogued.

LIBRARY

The reference library has continued under the immediate care of Miss Ella Leary, librarian, assisted by Mr. Thomas Blackwell. During the year 480 books were accessioned. Of these 100 were acquired by purchase, 280 by gift and exchange, and 100 by binding of periodicals. The periodicals currently received number about 975, of which 40 are by subscription, the remainder through exchange. The library has also received 187 pamphlets. The aggregate number of volumes in the library at the close of the year was 26,101; of pamphlets, 15,512; also several thousand unbound periodicals. The Library of Congress, officers of the executive departments, and out-of-town students have made use of the library through frequent loans during the year.

COLLECTIONS

The following collections, purchased or acquired by members of the bureau or by those detailed in connection with its researches, have been transferred to the United States National Museum:

83522. Small collection of ethnologia purchased by the bureau from Miss Emily S. Cook.

84260. Collection of archeological material secured by Mr. D. L. Reichard for the bureau, from Berryville, Va.

84444. Small stone celt, and a lot of pottery bowl ornaments from Porto Rico, presented to the bureau by Mrs. Alice de Santiago, Barceloneta, P. R.

85018. Collection of archeological material collected for the bureau by Gerard Fowke from mounds near Town Creek, Ala.

85019. Archeological material collected for the bureau by Dr. J. Walter Fewkes, from mounds near St. Petersburg, Fla.

85319. Archeological material collected for the bureau by Gerard Fowke, from mounds near Town Creek, Ala., on the site of the Wilson Dam, Muscle Shoals.

85343. Stone bird pipe found near Hydes Ferry, on the Cumberland River, about 7 miles below Nashville, Tenn.

85344. Five complete skulls and fragmentary remains of about twelve crania collected by Gerard Fowke from Hog Island Mound, near Town Creek, Ala. Five skulls collected by Earle O. Roberts, Harrah, Wash.

85780. Collection of skeletal material secured by Gerard Fowke at the Alexander Mound near Courtland, Ala.

85781. Collection of skeletal material which was unearthed 1¼ miles north of Boynton, Fla., and sent to the bureau by Mr. E. S. Jackson, of Palm Beach, Fla.

85824. Collection of archeological objects secured by Mr. J. O. Sanderson, of Courtland, Ala., and purchased by the bureau.

85856. Two pipes, one of steatite and the other of marble, collected for the bureau by Gerard Fowke from the Alexander Mound in Lawrence County, Ala.

87297. Collection of archeological material secured for the bureau at Youngs Canyon, about 18½ miles east of Flagstaff, Ariz., by Mr. J. C. Clarke, of Flagstaff.

83949. Human remains from Weeden Island, St. Petersburg, Fla., secured by the chief of the bureau during the winter of 1923–24.

MISCELLANEOUS

Clerical: The correspondence and other clerical work of the office has been conducted by Miss May S. Clark, clerk to the chief. Mr. Anthony W. Wilding, typist, has been engaged in copying manuscripts and in various duties connected with the office of the chief. Miss Julia Atkins, stenographer and typist, resigned October 15, 1924. Mrs. A. H. Kitchen was appointed temporarily December 13, 1924, for the three months, the appointment terminating March 13, 1925. Miss Mae W. Tucker was appointed temporarily May 1, 1925, as stenographer and typist.

Respectfully submitted.

J. Walter Fewkes, *Chief.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE INTERNATIONAL EXCHANGES

SIR: I have the honor to submit the following report on the operations of the International Exchange Service during the fiscal year ending June 30, 1925:

The congressional appropriation allowed for the support of the exchange service during the year 1925 was $49,550, $6,550 more than the amount granted for the fiscal year 1924. Of this increase about half was to cover the extra amount necessary for reclassification of salaries. The usual appropriation of $200 for printing and binding was granted by Congress. There was collected by the Institution on account of repayment from departmental and other establishments $4,900.22, making the total resources available for carrying on the Smithsonian system of exchanges for the fiscal year 1925 $54,650.22.

During the year the total number of packages handled was 468,731, an increase over the number for the preceding year of 8,073. These packages weighed a total of 506,164 pounds, a loss of 60,943 pounds. This decrease in weight is due to the smaller size of packages of publications received for transmission through the service.

The number and weight of the packages of different classes are indicated in the following table:

	Packages		Weight	
	Sent	Received	Sent	Received
			Pounds	*Pounds*
United States parliamentary documents sent abroad	198, 862		86, 337	
Publications received in return for parliamentary documents		4, 702		12, 851
United States departmental documents sent abroad	142, 911		158, 029	
Publications received in return for departmental documents		5, 734		20, 377
Miscellaneous scientific and literary publications sent abroad	90, 797		164, 018	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		25, 725		64, 552
	432, 570	36, 161	408, 384	97, 780
Grand total	468, 731		506, 164	

The value of the material passing through the International Exchange Service can not be estimated by the mere number of packages handled. Many of the packages each contain a number of valuable scientific publications. It may be estimated that annually there pass through the service both to and from foreign countries, considerably more than a million publications.

Although the United States Government sends abroad more publications than it receives in exchange, the disparity is not so great

as appears in the above table, for many foreign publications are received direct by mail by correspondents in this country.

Latvia, which joined both conventions in 1924, has established a service of international exchanges under the state library at Riga.

The total number of boxes used in despatching consignments was 2,325. This was a decrease of 139 from the preceding year and is accounted for by the smaller size of the packages received for transmission abroad, as referred to above. Of the total number of boxes shipped abroad, 268 were for the foreign depositories of full sets of United States governmental documents, and the remainder (2,057) was for distribution to miscellaneous establishments and individuals. While the Smithsonian Exchange Service, as a rule, transmits its consignments to other countries in boxes, sometimes the packages that accumulate for a particular country are not of sufficient bulk to warrant their transmission by freight, and they are mailed directly to their destinations. In addition, quite a number of packages are forwarded by mail to remote places which can not be reached through the existing exchange agencies. During the year the number of packages sent abroad in this manner was 39,499.

The number of boxes sent to each country is given in the following table:

Consignments of exchanges for foreign countries

Country	Number of boxes	Country	Number of boxes
Argentine Republic	43	Latvia	6
Austria	54	Lithuania	3
Belgium	58	Mexico	5
Bolivia	2	Netherlands	86
Brazil	34	New South Wales	29
British Colonies	11	New Zealand	22
Bulgaria	1	Nicaragua	1
Canada	20	Norway	33
Chile	22	Palestine	4
China	50	Paraguay	2
Chosen	6	Peru	19
Colombia	18	Poland	38
Costa Rica	12	Portugal	19
Cuba	5	Queensland	16
Czechoslovakia	80	Roumania	14
Danzig	3	Russia	98
Denmark	41	Salvador	2
Ecuador	2	Siam	3
Egypt	12	South Australia	20
Esthonia	10	Spain	36
Finland	20	Sweden	70
France	174	Switzerland	68
Germany	289	Tasmania	11
Great Britain and Ireland	303	Turkey	8
Greece	12	Union of South Africa	37
Guatemala	2	Uruguay	14
Honduras	2	Venezuela	10
Hungary	39	Victoria	40
India	42	Western Australia	11
Italy	98	Yugoslavia	17
Jamaica	2		
Japan	116	Total	2,325

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS

In accordance with the terms of a convention concluded at Brussels March 15, 1886, and under authority granted by Congress in resolutions approved March 2, 1867, and March 2, 1901, 58 full sets of United States official documents and 40 partial sets are now sent through the exchange service regularly to depositories abroad. This is a reduction of one full set from last year and an addition of two partial sets. New Zealand requested that a partial set be sent to the General Assembly Library instead of a full set. The Stadtbibliothek of the Free City of Danzig was added to the list of those receiving partial sets. The number of full and partial sets of governmental documents forwarded to foreign depositories therefore is 98. The total number provided by law for this purpose and for the use of the Library of Congress has been increased by act of Congress approved March 3, 1925, from 100 to 125.

The convention referred to above, which was the first of two conventions concluded at Brussels March 15, 1886, and is referred to as Convention A, provides for the international exchange of official documents and scientific and literary publications. The second convention, referred to as Convention B, provides for the interparliamentary exchange of the official journal as well as of the parliamentary annals and documents. Convention A was ratified by the United States, Belgium, Brazil, Italy, Portugal, Serbia, (now Yugoslavia), Spain, and Switzerland. Convention B was ratified by the same countries except Switzerland. Since the ratification of the Brussels conventions the following countries have signified their adherence thereto in the order in which they are listed:

1. Uruguay—both conventions, 1889.
2. Argentine Republic—convention A, 1889.
3. Paraguay—convention A, 1889.
4. Czechoslovakia—both conventions, 1919.
5. Poland—convention A, 1920; convention B, 1921.
6. Roumania—both conventions, 1923.
7. Hungary—both conventions, 1923.
8. Dominican Republic—both conventions, 1923.
9. Latvia—both conventions, 1924.
10. Free City of Danzig—both conventions, 1924.

It therefore will be seen that 18 countries have thus far joined the Brussels conventions of 1886. In order to give consideration to the question of having a larger number of countries adhere to the exchange conventions, the committee on intellectual cooperation of the League of Nations called together at Geneva in the summer of 1924 a committee of experts on the international exchange of publications, a brief report of which is given elsewhere.

At the request of the Governments of Finland and the United Provinces of Agra and Oudh, the depositories of partial sets of official documents have been changed from the Central Library of the State to the Parliamentary Library, and from the Colonial Secretary's office to the University of Allahabad, respectively.

The names of the depositories in foreign countries are given in the following list:

DEPOSITORIES OF FULL SETS

ARGENTINE REPUBLIC: Ministerio de Relaciones Exteriores, Buenos Aires.
AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
AUSTRIA: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.
BADEN: Universitäs-Bibliothek, Freiburg. (Depository of the State of Baden.)
BAVARIA: Staats-Bibliothek, Munich.
BELGIUM: Bibliothèque Royale, Brussels.
BRAZIL: Bibliotheca Nacional, Rio de Janeiro.
BUENOS AIRES: Biblioteca de la Universidad Nacional de la Plata. (Depository of the Province of Buenos Aires.)
CANADA: Library of Parliament, Ottawa.
CHILE: Biblioteca del Congreso Nacional, Santiago.
CHINA: American-Chinese Publication Exchange Department, Shanghai, Bureau of Foreign Affairs, Shanghai.
COLOMBIA: Biblioteca Nacional, Bogotá.
COSTO RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CUBA: Secretaría de Estado (Asuntos Generales y Canje Internacional), Habana.
CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DENMARK: Kongelige Bibliotheket, Copenhagen.
ENGLAND: British Museum, London.
ESTHONIA: Riigiraamatukogu (State Library), Reval.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Deutsche Reichstags-Bibliothek, Berlin.
GLASGOW: City Librarian, Mitchell Library, Glasgow.
GREECE: Bibliothèque Nationale, Athens.
HUNGARY: Hungarian House of Delegates, Budapest.
INDIA: Imperial Library, Calcutta.
IRISH FREE STATE: National Library of Ireland, Dublin.
ITALY: Biblioteca Nazionale Vittorio Emanuele, Rome.
JAPAN: Imperial Library of Japan, Tokyo.
LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
MANITOBA: Provincial Library, Winnipeg.
MEXICO: Biblioteca Nacional, Mexico.
NETHERLANDS: Bibliotheek van de Tweede Kamer der Staten-Generaal, The Hague.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NORTHERN IRELAND: Ministry of Finance, Belfast.
NORWAY: Universitets-Bibliotek, Oslo. (Depository of the Government of Norway.)
ONTARIO: Legislative Library, Toronto.

PARIS: Préfecture de la Seine.
PERU: Biblioteca Nacional, Lima.
POLAND: Bibliothèque du Ministère des Affairs Étrangères, Warsaw.
PORTUGAL: Bibliotheca Nacional, Lisbon.
PRUSSIA: Preussische staatsbibliothek, Berlin, N. W. 7.
QUEBEC: Library of the Legislature of the Province of Quebec, Quebec.
QUEENSLAND: Parliamentary Library, Brisbane.
RUSSIA: Shipments temporarily suspended.
SAXONY: Sächsische Landesbibliothek, Dresden—N. 6.
SOUTH AUSTRALIA: Parliamentary Library, Adelaide.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.
SWITZERLAND: Library of the League of Nations, Palace of Nations, Quai de Leman, Geneva.
TASMANIA: Parliamentary Library, Hobart.
TURKEY: Shipments temporarily suspended.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
WURTTEMBERG: Landesbibliothek, Stuttgart.
YUGOSLAVIA: Ministère des Affaires Étrangères, Belgrade.

DEPOSITORIES OF PARTIAL SETS

ALBERTA: Provincial Library, Edmonton.
ALSACE-LORRAINE: Bibliothèque Universitaire et Régionale de Strasbourg, Strasbourg.
BOLIVIA: Ministerio de Colonización y Agricultura, La Paz.
BRAZIL: Bibliotheca da Assemblea Legislativa do Estado do Rio de Janeiro, Nichtheroy.
BREMEN: Senatskommission für Reichs- und Auswärtige Angelegenheiten.
BRITISH COLUMBIA: Legislative Library, Victoria.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
BULGARIA: Ministère des Affairs Étrangères, Sofia.
CEYLON: Colonial Secretary's Office (Record Department of the Library), Colombo.
DANZIG: Stadtbibliothek, Free City of Danzig.
ECUADOR: Biblioteca Nacional, Quito.
EGYPT: Bibliothèque Khédiviale, Cairo.
FINLAND: Parliamentary Library, Helsingfors.
GUATEMALA: Secretary of the Government, Guatemala.
HAITI: Secrétaire d'État des Relations Extérieures, Port-au-Prince.
HAMBURG: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.
HESSE: Landesbibliothek, Darmstadt.
HONDURAS: Secretary of the Government, Tegucigalpa.
JAMAICA: Colonial Secretary, Kingston.
LATVIA: Bibliothèque d'État, Riga.
LIBERIA: Department of State, Monrovia.

LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.
LÜBECK: President of the Senate.
MADRAS, PROVINCE OF: Chief Secretary to the Government of Madras, Public Department, Madras.
MALTA: Minister for the Treasury, Valetta.
NEW BRUNSWICK: Legislative Library, Frederickton.
NEWFOUNDLAND: Colonial Secretary, St. John's.
NEW ZEALAND: General Assembly Library, Wellington.
NICARAGUA: Superintendente de Archivos Nacionales, Managua.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
PANAMA: Secretaría de Relaciones Exteriores, Panama.
PARAGUAY: Sección Canje Internacional de Publicaciones del Ministerio de Relaciones Exteriores, Estrella 563, Asunción.
PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.
ROUMANIA: Academia Romana, Bukharest.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SASKATCHEWAN: Government Library, Regina.
SIAM: Department of Foreign Affairs, Bangkok.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.
UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.
VIENNA: Bügermeister-Amt der Stadt Wien.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNAL

The interparliamentary exchange is conducted by the Smithsonian Institution in behalf of the United States Government under the authority granted in a congressional resolution approved March 4, 1909, the object of that resolution being to carry into effect the provisions of the second convention concluded at Brussels in 1886, providing for the immediate exchange of the Official Journal, the United States being one of the signatories to that convention.

The immediate exchange has been entered into during the year with India and the Free City of Danzig. The names of the establishments to which the daily issue of the Congressional Record is mailed are given below:

ARGENTINE REPUBLIC: Biblioteca del Congreso Nacional, Buenos Aires.
AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
AUSTRIA: Bibliothek des Nationalrates, Wien I.
BADEN: Universitäts-Bibiliothek, Heidelberg.
BELGIUM: Bibliothèque de la Chambre des Représentants, Brussels.
BOLIVIA: Cámara de Diputados, Congreso Nacional, La Paz.
BRAZIL: Bibliotheca do Congresso Nacional, Rio de Janeiro.
BUENOS AIRES: Biblioteca del Senado de la Provincia de Buenos Aires, La Plata.
CANADA:
Library of Parliament, Ottawa.
Clerk of the Senate, Houses of Parliament, Ottawa.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CUBA:
Biblioteca de la Cámara de Representantes, Habana.
Biblioteca del Senado, Habana.
CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DANZIG: Stadtbibliothek, Danzig.
DENMARK: Rigsdagens Bureau, Copenhagen.
ESTHONIA: Riigiraamatukogu (State Library), Reval.
FRANCE:
Bibliothèque de la Chambre des Députés, au Palais Bourbon, Paris.
Bibliothèque du Sénat, au Palais du Luxembourg, Paris.
GREAT BRITAIN: Library of the Foreign Office, Downing Street, London, S. W. 1.
GREECE: Library of Parliament, Athens.
GUATEMALA: Biblioteca de la Oficina Internacional Centro-Americana, 8a Calle Poniente No. 1, Ciudad de Guatemala.
HAITI: Secrétaire d'État des Relations Extérieures, Port-au-Prince.
HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.
HUNGARY: Bibliothek des Abgeordnetenhauses, Budapest.
INDIA: Legislative Library, Simla.
ITALY:
Biblioteca della Camera dei Deputati, Palazzo di Monte Citorio, Rome.
Biblioteca del Senato del Regno, Palazzo Madama, Rome.
LATVIA: Library of the Saeima, Riga.
LIBERIA: Department of State, Monrovia.
NEW SOUTH WALES: Library of Parliament, Sydney.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Stortingets Bibliotek, Oslo.
PERU: Cámara de Diputadoes, Congreso Nacional, Lima.
POLAND: Monsieur le Ministre des Affaires Étrangères, Warsaw.
PORTUGAL: Bibliotheca do Congresso da Republica, Lisbon.
PRUSSIA: Bibliothek des Abgeordnetenhauses, Prinz-Albrechtstrasse 5, Berlin, S. W. 11.
QUEENSLAND: Chief Secretary's Department, Brisbane.
ROUMANIA: Bibliothèque de la Chambre des Députés, Bukharest.
SPAIN:
Biblioteca del Congreso de los Diputados, Madrid.
Biblioteca del Senado, Madrid.
SWITZERLAND:
Bibliothèque de l'Assemblée Fédérale Suisse, Berne.
Library of the League of Nations, Geneva.
TRANSVAAL: State Library, Pretoria.
UNION OF SOUTH AFRICA: Library of Parliament, Cape Town.
URUGUAY: Biblioteca de la Cámara de Representantes, Montevideo.
VENEZUELA: Cámara de Diputados, Congreso Nacional, Caracas.
WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.
YUGOSLAVIA: Library of the Skupshtina, Belgrade.

There are at present 43 different foreign States or Provinces with which the immediate exchange of the Official Journal is carried on. To some of the countries two copies of the Congressional Record are forwarded—one to the upper and one to the lower house of Parliament. The total number of records transmitted is 49. The number of copies of the record set aside by law for this purpose is 100.

FOREIGN EXCHANGE AGENCIES

A complete list of the foreign exchange agencies or bureaus is given below:

ALGERIA, *via* France.
ANGOLA, *via* Portugal.
ARGENTINE REPUBLIC: Comisión Protectora de Bibliotecas Populares, Calle Córdoba 931, Buenos Aires.
AUSTRIA: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.
AZORES, *via* Portugal.
BELGIUM: Service Belge des Échanges Internationaux, Rue des Longs-Chariots 46, Brussels.
BOLIVIA: Oficina Nacional de Estadística, La Paz.
BRAZIL: Serviço de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
BRITISH COLONIES: Crown Agents for the Colonies, London.
BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.
BRITISH HONDURAS: Colonial Secretary, Belize.
BULGARIA: Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.
CANARY ISLANDS, *via* Spain.
CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.
CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
CHOSEN: Government General, Keijo.
COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CZECHOSLOVAKIA: Service Tchécoslovaque des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1–79.
DANZIG: Amt für den Internationalen Schriftenaustausch der Freien Stadt Danzig, Stadtbibliothek, Danzig.
DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.
DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.
ECUADOR: Ministerio de Relaciones Exteriores, Quito.
EGYPT: Sent by mail.
ESTHONIA: Riigiraamatukogu (State Library), Reval.
FINLAND: Delegation of the Scientific Societies of Finland, Helsingfors.
FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.
GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.
GREAT BRITAIN AND IRELAND: Messrs. Wheldon & Wesley, 2, 3, and 4 Arthur St., New Oxford St., London, W. C. 2.
GREECE: Bibliothèque Nationale, Athens.
GREENLAND, *via* Denmark.
GUATEMALA: Instituto Nacional de Varones, Guatemala.
HAITI: Secrétaire d'État des Relations Extérieures, Port-au-Prince.
HONDURAS: Biblioteca Nacional, Tegucigalpa.
HUNGARY: Service Hongrois des Échanges Internationaux, Musée Nationale, Budapest, VIII.
ICELAND, *via* Denmark.
INDIA: Superintendent of Stationery, Bombay.

ITALY: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.
JAMAICA: Institute of Jamaica, Kingston.
JAPAN: Imperial Library of Japan, Tokyo.
JAVA, *via* Netherlands.
LATVIA: Service des Échanges Internationaux, Bibliothèque d'État de Lettonie, Riga.
LIBERIA: Bureau of Exchanges, Department of State, Monrovia.
LITHUANIA: Sent by mail.
LOURENÇO MARQUEZ, *via* Portugal.
LUXEMBURG, *via* Belgium.
MADAGASCAR, *via* France.
MADEIRA, *via* Portugal.
MOZAMBIQUE, *via* Portugal.
NETHERLANDS: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Académie Technique, Delft.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NEW ZEALAND: Dominion Museum, Wellington.
NICARAGUA: Ministerio de Relaciones Exteriores, Managua.
NORWAY: Universitets-Bibliotek, Oslo.
PANAMA: Secretaría de Relaciones Exteriores, Panama.
PARAGUAY: Sección Canje Internacional de Publicaciones del Ministerio de Relaciones Exteriores, Estrella 563, Asuncion.
PERU: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.
POLAND: Service Polonais des Échanges Internationaux, Bibliothèque du Ministère des Affaires Étrangères, Warsaw.
PORTUGAL: Secção de Trocas Internacionaes, Bibliotheca Nacional, Lisbon.
QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Department, Brisbane.
ROUMANIA: Bureau des Échanges Internationaux, Institut Meteorologique Central, Bukharest.
RUSSIA: Academy of Sciences, Leningrad.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SIAM: Department of Foreign Affairs, Bangkok.
SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SUMATRA, *via* Netherlands.
SWEDEN: Kongliga Svenska Vetenskaps Akademien, Stockholm.
SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Berne.
SYRIA: American University of Beirut.
TASMANIA: Secretary to the Premier, Hobart.
TRINIDAD: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.
TUNIS, *via* France.
TURKEY: Robert College, Constantinople.
UNION OF SOUTH AFRICA: Government Printing Works, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Carácas.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
YUGOSLAVIA: Académie Royale Serbe des Sciences et des Arts, Belgrade.

COMMITTEE OF EXPERTS ON THE INTERNATIONAL EXCHANGE OF PUBLICATIONS, GENEVA, SWITZERLAND

The committee on intellectual cooperation of the League of Nations called together at Geneva July 17–19, 1924, a committee of experts on the international exchange of publications, of which Prof. O. de Halecki, of the University of Warsaw, was made chairman. Mr. H. W. Dorsey, chief clerk of the Institution, who has been closely in touch with the exchange service for many years, was sent as the Smithsonian representative. The other members of the committee were Mr. J. Luchaire, Inspector General of Public Education of France; Mr. E. Bacha, Director of the Belgian Service of International Exchanges; Mr. V. Benedetti, Director of the Italian Service of International Exchanges; and Mr. B. M. Headicar, Librarian of the London School of Economics and Political Science.

The above committee, without making any change in the Brussels convention of 1886, recommended an additional protocol, enabling the states that are not yet parties to the convention to adhere thereto with reservations. The resolutions of the committee of experts regarding this matter are as follows:

The states which have not yet adhered to the convention of 1886 and might consider the obligation carried in Article II as too burdensome, either on account of the very great number of their official publications or on account of their financial condition, or on any other ground, may accept the convention with the reservation that they would agree with each nation as to the number of publications to be sent. The exchange of those states with states that have unreservedly adhered to the convention would be governed by the same principle.

The Belgian Government is asked kindly to make a text of the foregoing resolution known to the states parties to the convention of March 15, 1886. These states will at the same time be informed that partial adhesions that may occur under this resolution would be made known to them by the same Government as fast as they took place, the said adhesions becoming compulsory only as between the said parties that accepted them and the adhering states.

All applications for partial adhesion would be made known to the Belgian Government and notified by that Government to every one of the states parties to the convention of 1886, including those who shall have been allowed to give partial adhesion to that treaty, each one of the states being at the same time requested to advise the said Government within one year after the date of such notification whether, so far as it is concerned, it has accepted the partial adhesion. Any state which shall not have notified its acceptance within that time shall be considered as refusing to accept the adhesion.

These resolutions were brought to the attention of this Government by the Belgian Government. The Department of State referred the matter to the Smithsonian Institution, which replied that it saw

no objection to the assent of this Government to the principle of limited adhesions to the exchange convention of 1886. It was pointed out, however, that as the principle of partial exchange of official documents has been adopted by the United States Government, the proposed reservations to the convention would not materially affect the exchange conditions now existing between the United States and other countries.

The committee of experts considered not only the possibility of improving the exchange of official documents as referred to above, but also the best way of encouraging the exchange of scientific and literary works. The committee's recommendations are embodied in the following extract from a draft convention:

ARTICLE I. Independently of the obligations which might result for each of them from the previous conventions relative to the exchange of publications, the high contracting parties undertake to exchange, as fast as they are published, at least one copy—

(*a*) All the current repertories of national bibliography of a general character.

(*b*) As far as possible documents of every kind giving information on the recent acquisitions of their scientific libraries.

ART. II. Each contracting State agrees to take all measures which it judges desirable—

(*a*) In order to make easily accessible to all interested parties the lists communicated to it according to Article I.

(*b*) In order to secure favorable consideration of all the proposals of exchange which might be addressed to it by all the contracting States with regard to scientific or literary publications included in the above-mentioned lists.

ART. III. To facilitate generally the exchange of works which are the most important or most representative of the various types of national culture, the high contracting parties shall collect or catalogue the publications received by gift or otherwise which are available for international exchange. They will publish from time to time a list of these works.

This list will also give the names of works existing in duplicate in libraries which may be exchanged.

ART. IV. The high contracting parties undertake to encourage in every way the multiplication of exchanges of scientific and literary publications, whether State-subsidized or not, between academies and learned societies, universities, and scientific institutions, as laid down in Article VII of the Convention of 1886.

ART. V. The high contracting parties undertake to publish annual reports on the work of their exchange services. These reports shall be transmitted to the committee on intellectual cooperation, which shall publish extracts therefrom, together with a general report on the work of the international exchanges during the period in question.

The text of the above draft convention was brought to the attention of this Government by the secretary general of the League of Nations with the request that consideration be given to the feasi-

bility of agreeing to it. The State Department referred the matter to the Institution, which replied in part as follows:

> While it is realized that the articles in the proposed new convention would greatly facilitate the dissemination and interchange of published information among the various countries, it is also realized that it would be impossible to carry out their stipulations even partially without the expenditure of a considerable sum of money annually. So far as the Smithsonian Institution is concerned, it would be impossible to do so without a large increase in the appropriation made to it for the support of the International Exchange Service.
>
> The Smithsonian Institution is, therefore, not in a position to carry out even partially the terms proposed in the new convention unless adequate additional funds were appropriated for the purpose. The Institution has, however, always done everything in its power to promote this subject since it inaugurated a system of international exchange in 1850, and believes that it might be well for this country to consider again at a later and more favorable time the question of adhering to the proposed convention.

The committee of experts also gave consideration to various other matters looking to the improvement of the international exchange service at large and the extension of its activities.

Respectfully submitted.

C. G. Abbot,
Assistant Secretary, in charge of Library and Exchanges.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1925.

Mr. N. Hollister, superintendent of the park since 1916, died on November 3, 1924, and was succeeded by Dr. Alexander Wetmore, who served until April 1, 1925. On that date Doctor Wetmore was appointed an assistant secretary of the Smithsonian Institution, and the writer was honored by appointment as superintendent of the park on May 13, 1925.

The appropriation made by Congress for the regular maintenance of the park was $148,237. From the printing and binding appropriation of the Smithsonian Institution, $300 was allotted to the National Zoological Park. A special appropriation of $3,250 was made by Congress for laying a water main and installing two fire hydrants in the park. This sum proved to be inadequate, and it was necessary to allot money from the regular maintenance fund of the park to complete the work.

As regards the collection, the year has not been a satisfactory one. Many of the specimens in the park representing major types of animals are very old, and occasional deaths are beginning to thin their ranks, as has been expected, which has resulted during the past year in the loss of valuable specimens in several representative groups, thus greatly diminishing the value of the collection.

ACCESSIONS

Gifts.—One hundred and thirty animals were presented to the park or placed there on indefinite deposit during the year. Notable among these are the splendid young male chimpanzee and a pair of turacous placed on deposit by Mr. Victor J. Evans, who maintains a continual interest in the collection; a series of five valuable monkeys presented by Mr. and Mrs. E. R. Grant, of Washington, D. C.; a Bateleur eagle, an Abyssinian falcon, and two South American stone plover, by Mr. B. H. Swales; a brocket deer by Mr. P. W. Shufeldt, of Belize, British Honduras; a black bear by Mr. Fred N. Bent, of De Leon Springs, Fla.; and a large monitor lizard by Capt.

Walter K. Burgess, United States Army. A complete list of gifts for the year from 70 individual donors is as follows:

Mr. E. R. Acher, Washington, D. C., Virginia opossum.

Mr. J. M. Annadale, Washington, D. C., Virginia opossum.

Mr. C. R. Aschemeier, Washington, D. C., chicken turtle, 2 gopher tortoises, and Florida snapping turtle.

Mr. Vernon Bailey, Biological Survey, Washington, D. C., white-headed beach mouse and 5 grasshopper mice.

Dr. Barnhart, Washington, D. C., mockingbird.

Mr. O. E. Baynard, Plant City, Fla., Florida barred owl and bald eagle.

Mr. J. T. Benson, Nashua, N. H., Nepalese paroquet.

Mrs. L. A. Bostwick, Washington, D. C., 2 Tovi paroquets.

Mr. M. K. Brady, Washington, D. C., Chinese, Japanese, and American tortoises and terrapins.

Capt. Walter K. Burgess, United States Army, monitor lizard.

Mr. Fred N. Burt, De Leon Springs, Fla., black bear.

Miss Helen Carlisle, Washington, D. C., brown capuchin.

Mr. H. C. Chandlee, Washington, D. C., Cuban parrot.

President Coolidge. White House, alligator.

Mrs. S. E. De Maret, Washington, D. C., canary and red-and-blue-and-yellow macaw.

Mrs. H. O. Earle, Washington, D. C., alligator.

Mr. E. H. Ehlis, Washington, D. C., screech owl.

Mr. Will Ellis, Niagara Falls, Ontario, banded rattlesnake.

Mr. V. J. Evans, chimpanzee, 2 turacous, and 2 chukker partridges.

Mr. Charles L. Fagan, Rahway, N. J., Hungarian quail, bobolink, and Gay's finch.

Mr. Robert W. Ferguson, Boston, Mass., wild turkey.

Mrs. Robert W. Ferguson, Fernandina, Fla., 3 rattlesnakes.

Mr. E. K. Fox, Washington, D. C., black-crowned night heron.

Mr. A. G. P. Garrett, jr., Washington, D. C., raccoon.

Mrs. E. H. Gilford, Washington, D. C., Philippine macaque.

Dr. W. S. Gochenour, Bureau of Animal Industry, Department of Agriculture, Washington, D. C., 5 mallards.

Mr. E. R. Grant, Washington, D. C., mandrill, Gelada baboon, yellow baboon, and sphinx baboon.

Mrs. E. R. Grant, Washington, D. C., lesser white-nosed guenon.

Mr. Arthur Harris, Washington, D. C., ring-necked pheasant.

Mr. Thomas Harrison, Washington, D. C., alligator.

Miss Ina L. Hawes, Bureau of Entomology, Washington, D. C., horned toad.

Mr. Joseph Hayden, Washington, D. C., grass paroquet.

Mr. Owen Hockman, Washington, D. C., barred owl.

Mr. E. H. Holbrook, Maupin, Oreg., black bear.

Mrs. M. J. Holmes, Washington, D. C., blue jay.

Mr. W. F. Hopkins, Washington, D. C., painted turtle.

Mr. I. S. Horne, Kansas City, Mo., 12 prairie dogs.

Mr. Clyde Howard, Huntley, Mont., coyote.

Mr. Francis Jaffee, Washington, D. C., St. Helena waxbill.

Mr. F. N. Jarvis, Biological Survey, Washington, D. C., American barn owl and Cooper's hawk.

Mr. E. J. Jutz, Washington, D. C., Margay cat.

Miss Virginia Kalmbach, Washington, D. C., canary.

Mr. Francis S. Key, Washington, D. C., alligator.

Mr. Jerome Keyes, Alexandria, Va., spreading adder.

Mr. John M. Klein, Washington, D. C., blue-fronted parrot.

Maj. Frank G. Long, United States Army, red-and-blue-and-yellow macaw.

Dr. William M. Mann, African tortoises, Reeves turtle, and blue-headed parrot.

Mr. Herbert Manning, Washington, D. C., alligator.

Miss Merla G. Matthews, Washington, D. C., alligator.

Mrs. J. W. McClure, Sebring, Fla., two sandhill cranes.

Miss Lelia M. Milstead, Newington, Va., Virginia opossum.

Mrs. J. W. Morse, Washington, D. C., alligator.

Mrs. D. W. Padden, Fredonia, N. Y., double yellow-head parrot.

Dr. Pardoe, Bound Brook, N. J., pine snake.

Mrs. S. F. Perkins, Washington, D. C., two snapping turtles and two painted turtles.

Mr. E. L. Phillips, Washington, D. C., alligator.

Mr. J. H. Pilling, Falls Church, Va., brown capuchin.

Mrs. R. H. Quinn, Washington, D. C., common rabbit.

Mr. E. D. Reid, United States National Museum, Washington, D. C., pilot black snake.

Mr. H. W. Richards, Takoma Park, Md., two screech owls.

Mr. L. B. Robertson, Clarendon, Va., bonnet monkey.

Mr. J. T. Russell, Washington, D. C., Petz paroquet.

Mr. R. C. Shannon, United States National Museum, Washington, D. C., copperhead snake.

Mr. John B. Shepard, Albany, N. Y., muskrat.

Mr. P. W. Shufeldt, Belize, B. H., brocket.

Mr. Carl H. Smith, Washington, D. C., orange-winged paroquet.

Dr. T. E. Snyder, Bureau of Entomology, Washington, D. C., spreading adder.

Mr. B. H. Swales, Washington, D. C., South American stone plover; pigmy falcon, and Bateleur eagle.

Mr. J. E. Tyler, Washington, D. C., canary.

Mrs. R. C. Wilton, Washington, D. C., blue-and-yellow macaw.

Mr. H. A. Wrenn, Baltimore, Md., albino squirrel.

Births.—During the year 74 birds and mammals, hatched or born at the park, were added to the collection. Among the mammals were: Manchurian tiger, 3; plains wolf, 3; coyote, 5; European brown bear, 4; Rocky Mountain sheep, 3; mouflon, 1; tahr, 2; American bison, 3; yak, 1; Indian buffalo, 1; black buck, 1; American elk, 1; red deer, 4; Barasingha deer, 1; Japanese deer, 4; fallow deer, 3; hippopotamus, 1; grasshopper mouse, 5; rhesus monkey, 1; Javan macaque, 1; Japanese macaque, 1; flying phalanger, 1; great red kangaroo, 3; rufous-bellied wallaby, 1; brush-tailed rock wallaby, 1.

The park was again fortunate in raising two blue geese *(Chen cærulescens)*. Other birds hatched were as follows: Mute swan, black duck, peafowl, silver gull, and black-crowned night heron.

Purchases, exchanges, and transfers.—Only 91 specimens were purchased during the year. Of these special mention should be made of a De Brazza's guenon, a serval, a pair of viscachas, an Arabian gazelle, a llama, and a male gemsbok. The last named is a magnificent specimen, the second of its kind to be received at the park.

A small number of animals were received in exchange for surplus stock from the collection.

The Biological Survey, United States Department of Agriculture, transferred a number of animals taken by field agents of the bureau, including some large western ravens, western porcupines, two sandhill cranes, and two whistling swans.

Deposits.—Among the animals received on deposit, which represented species not exhibited in the collection, were a sarus crane, a jabiru stork, and a pair of adjutants, deposited for a time by Mr. Victor J. Evans. Of species placed on deposit which were new to the park records, a lesser white-nosed guenon is especially notable.

REMOVALS

Forty-one birds and mammals were sent away in exchange to other zoological gardens during the year. Among these were two elk, an Indian buffalo, two American bison, six red deer, four Japanese deer, and a llama.

Nine animals and birds on deposit were returned to their owners.

The average mortality among the animals remains low, despite numerous losses during the year, chiefly among aged animals, long on exhibition. These losses, however, have been very serious, as they include a bull eland that had lived in the park since 1916, a Grant zebra received in 1909, a Rocky Mountain sheep ram received in 1917, Barbados sheep, reindeer, a wart hog, two lions, a male Axis deer, an African leopard that had lived in the park since 1909, and an African rhinoceros that had been in the collection only 18 months. Most of these animals were the only representatives of their species in the collection, and their loss creates gaps that can be filled only by purchases involving expenditures of far more money than is available.

Losses among reptiles are so heavy unless adequate arrangements are made for their care, that it is useless to attempt to maintain a collection in this group, except of a few hardy types, until proper quarters are provided for them.

Post-mortem examinations of animals that died were made, when desired, by the pathological division of the Bureau of Animal Industry.

The following list shows the results of autopsies, the causes being arranged in groups:

MAMMALS

Marsupialia: Pneumonia, 3; pleurisy and pericarditis, 1; gastroenteritis, 1; necrobacillosis, 3; no cause found, 1.

Carnivora: Chronic nephritis, 1; internal hemorrhage, 1; cystic goitre, 1; no cause found, 1.

Rodentia: Pneumonia, 1; necrosis of jaw, 1; no cause found, 1.

Edentata: Congestion of lungs, 1; no cause found, 1.

Primates: Congestion of lungs, 1; icterus, 1; metritis, 1; cystic tumor, 1; ankylosis, 1; cage paralysis, 1.

Artiodactyla: Pneumonia, 3; enteritis, 2; gastroenteritis, 1; acute indigestion, 1; impaction of rumen, 2; old age, 6; accident, 1; difficult parturition, 1.

Perissodactyla: Round worm infestation, 1; volvulus of large intestine, 1.

Proboscidea: Malignant tumor, 1.

Insectovora: Gastroenteritis, 1.

BIRDS

Ciconiiformes: Impaction of crop, 1; accident, 1; no cause found, 2.

Anseriformes: Tuberculosis, 2; gastroenteritis, 1; visceral gout, 1; verminous obstipation, 1; no cause found, 5.

Falconiformes: Accident, 1.

Galliformes: Accident, 1.

Gruiformes: Accident, 1.

Charadriiformes: Enteritis, 1; visceral gout, 1.

Psittaciformes: Tuberculosis, 2; coccidiosis, 1.

Coraciiformes: Tuberculosis, 1; volvulus of large intestine, 1.

Passeriformes: Syncope, 1; tapeworm infestation, 1; no cause found, 1.

ANIMALS IN THE COLLECTION, JUNE 30, 1925

MAMMALS

MARSUPIALIA

Allen's opossum (*Metachirops opossum fuscogriseus*)	1
Virginia opossum (*Didelphis virginiana*)	10
Tasmanian devil (*Sarcophilus harrisii*)	2
Australian opossum (*Trichosurus vulpecula*)	1
Flying phalanger (*Petaurus breviceps*)	7
Brush-tailed rock wallaby (*Petrogale penicillata*)	3
Rufous-bellied wallaby (*Macropus billardierii*)	3
Wallaroo (*Macropus robustus*)	1
Great gray kangaroo (*Macropus giganteus*)	2
Red kangaroo (*Macropus rufus*)	6
Wombat (*Phascolomys mitchelli*)	1

CARNIVORA

Kadiak bear (*Ursus middendorffi*)	2
Alaska Peninsula bear (*Ursus gyas*)	4
Yakutat bear (*Ursus dalli*)	1
Kidder's bear (*Ursus kidderi*)	2
European bear (*Ursus arctos*)	6
Grizzly bear (*Ursus horribilis*)	1
Apache grizzly (*Ursus apache*)	1
Himalayan bear (*Ursus thibetanus*)	1
Black bear (*Ursus americanus*)	4
Cinnamon bear (*Ursus americanus cinnamomum*)	2
Glacier bear (*Ursus emmonsii*)	1
Sloth bear (*Melursus ursinus*)	1
Sun bear (*Helarctos malayanus*)	1
Polar bear (*Thalarctos maritimus*)	2
Dingo (*Canis dingo*)	3
Gray wolf (*Canis nubilus*)	7
Timber wolf (*Canis occidentalis*)	1
Florida wolf (*Canis floridanus*)	1
Texas red wolf (*Canis rufus*)	1
Coyote (*Canis latrans*)	7
Hybrid coyote (*Canis latrans-rufus*)	1
California coyote (*Canis ochropus*)	1
Black-backed jackal (*Canis mesomelas*)	1
Red fox (*Vulpes fulva*)	4
European fox (*Vulpes vulpes*)	1
Kit fox (*Vulpes velox*)	2
Gray fox (*Urocyon cinereoargenteus*)	2
Bush dog (*Icticyon venaticus*)	1
Cacomistle (*Bassariscus astutus*)	2
Panda (*Ailurus fulgens*)	1
Raccoon (*Procyon lotor*)	7
Florida raccoon (*Procyon lotor elucus*)	2
Gray coatimundi (*Nasua narica*)	2
Kinkajou (*Potos flavus*)	3
Mexican kinkajou (*Potos flavus aztecus*)	1
American badger (*Taxidea taxus*)	2
Florida otter (*Lutra canadensis vaga*)	3
Black-footed ferret (*Mustela nigripes*)	1
Palm civet (*Paradoxurus hermaphroditus*)	2

Aard-wolf (*Proteles cristatus*)	1
Spotted hyena (*Crocuta crocuta*)	1
Striped hyena (*Hyæna hyæna*)	1
African cheetah (*Acinonyx jubatus*)	2
Lion (*Felis leo*)	5
Bengal tiger (*Felis tigris*)	1
Manchurian tiger (*Felis tigris longipilis*)	5
Leopard (*Felis pardus*)	1
Jaguar (*Felis onca*)	1
Serval (*Felis serval*)	1
Brazilian ocelot (*Felis pardalis brasiliensis*)	1
Snow leopard (*Felis uncia*)	1
Mexican puma (*Felis azteca*)	4
Mountain lion (*Felis hippolestes*)	1
Canada lynx (*Lynx canadensis*)	1
Northern wild cat (*Lynx uinta*)	1
Bay lynx (*Lynx rufus*)	2
Clouded leopard (*Neofelis nebulosa*)	1

PINNIPEDIA

California sea lion (*Zalophus californianus*)	2
San Geronimo harbor seal (*Phoca richardii geronimensis*)	1

RODENTIA

Woodchuck (*Marmota monax*)	3
Prairie dog (*Cynomys ludovicianus*)	36
European squirrel (*Sciurus vulgaris*)	4
Prevost's squirrel (*Sciurus prevosti*)	1
Honduras squirrel (*Sciurus boothiæ*)	1
Albino squirrel (*Sciurus carolinensis*)	3
Bailey's pocket mouse (*Perognathus baileyi*)	1
White-headed beach mouse (*Peromyscus leucocephalus*)	1
American beaver (*Castor canadensis*)	5
Grasshopper mouse (*Onychomys leucogaster*)	10
African porcupine (*Hystrix africæaustralis*)	1
Malay porcupine (*Acanthion brachyurum*)	2
Tree porcupine (*Coendou prehensilis*)	1
Western porcupine (*Erethizon epixanthum*)	1
Viscacha (*Lagostomus trichodactylus*)	2
Central American paca (*Cuniculus paca virgatus*)	3
Sooty agouti (*Dasyprocta fuliginosa*)	1
Speckled agouti (*Dasyprocta punctata*)	2
Azara's agouti (*Dasyprocta azaræ*)	1
Trinidad agouti (*Dasyprocta rubrata*)	5
Yellow-rumped agouti (*Dasyprocta lucifer cayennæ*)	1
Guinea pig (*Cavia porcellus*)	10
Capybara (*Hydrochœrus hydrochœrus*)	2

LAGOMORPHA

Domestic rabbit (*Oryctolagus cuniculus*)	10

INSECTIVORA

European hedgehog (*Erinaceus europæus*)	5

PRIMATES

Ring-tailed lemur (*Lemur catta*)	1
Red-fronted lemur (*Lemur rufifrons*)	1
Gray spider monkey (*Ateles geoffroyi*)	2
Mexican spider monkey (*Ateles neglectus*)	1
White-throated capuchin (*Cebus capucinus*)	4
Weeping capuchin (*Cebus apella*)	1
Brown capuchin (*Cebus fatuellus*)	3
Gelada baboon (*Theropithecus obscurus*)	1
Chacma (*Papio porcarius*)	1
Anubis baboon (*Papio cynocephalus*)	1
East African baboon (*Papio ibeanus*)	1
Arabian baboon (*Papio hamadryas*)	2
Mandrill (*Papio sphinx*)	2
Drill (*Papio leucophæus*)	1
Moor macaque (*Cynopithecus maurus*)	2
Barbary ape (*Simia sylvanus*)	2
Japanese macaque (*Macaca fuscata*)	3
Pig-tailed monkey (*Macaca nemestrina*)	1
Burmese macaque (*Macaca andamanensis*)	1
Rhesus monkey (*Macaca rhesus*)	18
Bonnet monkey (*Macaca sinica*)	1
Philippine macaque (*Macaca syrichta*)	1
Javan macaque (*Macaca mordax*)	6
Black mangabey (*Cercocebus aterrimus*)	1
Sooty mangabey (*Cercocebus fuliginosus*)	2
Hagenbeck's mangabey (*Cercocebus hagenbecki*)	1
White-collared mangabey (*Cercocebus torquatus*)	1
Green guenon (*Lasiopyga callitrichus*)	2
Vervet guenon (*Lasiopyga pygerythra*)	1
Mona guenon (*Lasiopyga mona*)	3
De Brazza's guenon (*Lasiopyga brazzæ*)	1
Lesser white-nosed guenon (*Lasiopyga petaurista*)	1
Chimpanzee (*Pan satyrus*)	2

ARTIODACTYLA

Wild boar (*Sus scrofa*)	1
Collared peccary (*Pecari angulatus*)	2
Hippopotamus (*Hippopotamus amphibius*)	3
Bactrian camel (*Camelus bactrianus*)	2
Arabian camel (*Camelus dromedarius*)	1
Guanaco (*Lama guanicoe*)	3
Llama (*Lama glama*)	6
Reindeer (*Rangifer tarandus*)	5
Fallow deer (*Dama dama*)	9
Axis deer (*Axis axis*)	2
Hog deer (*Hyelaphus porcinus*)	3
Sambar (*Rusa unicolor*)	2
Barasingha (*Rucervus duvaucelii*)	6
Burmese deer (*Rucervus eldii*)	1
Japanese deer (*Sika nippon*)	12
Red deer (*Cervus elaphus*)	13
Kashmir deer (*Cervus hanglu*)	2
Bedford deer (*Cervus xanthopygus*)	5
American elk (*Cervus canadensis*)	4

Virginia deer (*Odocoileus virginianus*)	1
Brocket (*Mazama sartorii*)	1
Blesbok (*Damaliscus albifrons*)	2
White-tailed gnu (*Connochætes gnou*)	1
Brindled gnu (*Connochætes taurinus*)	1
Lechwe (*Onotragus leche*)	1
Sable antelope (*Egocerus niger*)	1
Indian antelope (*Antilope cervicapra*)	4
Arabian gazelle (*Gazella arabica*)	1
Nilgai (*Boselaphus tragocamelus*)	2
Gemsbok (*Oryx gazella*)	1
East African eland (*Taurotragus oryx livingstonii*)	1
Mountain goat (*Oreamnos americanus*)	5
Tahr (*Hemitragus jemlahicus*)	8
Alpine ibex (*Capra ibex*)	2
Sheep (*Ovis ovis*)	1
Aoudad (*Ammotragus lervia*)	1
Rocky Mountain sheep (*Ovis canadensis*)	7
Arizona mountain sheep (*Ovis canadensis gaillardi*)	1
Mouflon (*Ovis musimon*)	4
Greenland musk-ox (*Ovibos moschatus Wardi*)	2
Zebu (*Bos indicus*)	1
Yak (*Pocphagus grunniens*)	5
American bison (*Bison bison*)	15
Indian buffalo (*Bubalus bubalis*)	3

PERISSODACTYLA

Malay tapir (*Tapirus indicus*)	1
Brazilian tapir (*Tapirus terrestris*)	1
Baird's tapir (*Tapirella bairdii*)	1
Grevy's zebra (*Equus grevyi*)	1
Zebra-horse hybrid (*Equus Grevyi-caballus*)	1
Zebra-ass hybrid (*Equus grevyi-asinus*)	1

PROBOSCIDEA

Abyssinian elephant (*Loxodonta africana oxyotis*)	1
Sumatran elephant (*Elephas sumatranus*)	1

BIRDS

RATITÆ

South African ostrich (*Struthio australis*)	5
Somaliland ostrich (*Struthio molybdophanes*)	2
Nubian ostrich (*Struthio camelus*)	1
Rhea (*Rhea americana*)	1
Sclater's cassowary (*Casuarius philipi*)	1
Emu (*Dromiceius novæhollandiæ*)	2
Kiwi (*Apteryx mantelli*)	1

CICONIIFORMES

American white pelican (*Pelecanus erythrorhynchos*)	7
European white pelican (*Pelecanus onocrotalus*)	2
Roseate pelican (*Pelecanus roseus*)	2
Australian pelican (*Pelecanus conspicillatus*)	2
Brown pelican (*Pelecanus occidentalis*)	9
California brown pelican (*Pelecanus californicus*)	5
Florida cormorant (*Phalacrocorax auritus floridanus*)	3
Great white heron (*Ardea occidentalis*)	2
Great blue heron (*Ardea herodias*)	1
Goliath heron (*Ardea goliath*)	1
American egret (*Casmerodius egretta*)	2
Black-crowned night heron (*Nycticorax nycticorax nævius*)	32
White stork (*Ciconia ciconia*)	1
Black stork (*Ciconia nigra*)	1
Marabou stork (*Leptoptilus crumentiferus*)	2
Indian jabiru (*Xenorhynchus asiaticus*)	1
Wood ibis (*Mycteria americana*)	4
Straw-necked ibis (*Carphibis spinicollis*)	1
Sacred ibis (*Threskiornis æthiopicus*)	2
Black-headed ibis (*Threskiornis melanocephalus*)	3
Australian ibis (*Threskiornis strictipennis*)	4
White ibis (*Guara alba*)	10
Scarlet ibis (*Guara rubra*)	4
European flamingo (*Phœnicopterus roseus*)	4

ANSERIFORMES

Mallard (*Anas platyrhynchos*)	9
Black duck (*Anas rubripes*)	8
Australian black duck (*Anas superciliosa*)	1
Gadwall (*Chaulelasmus streperus*)	1
Falcated duck (*Eunetta falcata*)	1
European widgeon (*Mareca penelope*)	3
Baldpate (*Mareca americana*)	8
Green-winged teal (*Nettion carolinense*)	11
European teal (*Nettion crecca*)	4
Baikal teal (*Nettion formosum*)	6
Blue-winged teal (*Querquedula discors*)	1
Garganey (*Querquedula querquedula*)	6
Shoveller (*Spatula clypeata*)	4
Pintail (*Dafila acuta*)	16
Bahaman pintail (*Poecilonetta bahamensis*)	1
Wood duck (*Aix sponsa*)	10
Mandarin duck (*Dendronessa galericulata*)	12
Canvasback (*Marila valisineria*)	9

European pochard (*Marila ferina*) 3
Redhead (*Marila americana*) 11
Ring-necked duck (*marila collaris*) 2
Tufted duck (*Marila fuligula*) 1
Lesser scaup duck (*Marila affinis*) 3
Greater scaup duck (*Marila marila*) 9
Rosy-billed pochard (*Metopiana peposaca*) 4
Egyptian goose (*Chenalopex ægyptiacus*) 3
Upland goose (*Chloephaga leucoptera*) 1
Hawaiian goose (*Nesochen sandvicensis*) 2
Snow goose (*Chen hyperboreus*) 1
Greater snow goose (*Chen hyperboreus nivalis*) 2
Blue goose (*Chen cærulescens*) 5
White-fronted goose (*Anser albifrons*) 2
American white-fronted goose (*Anser albifrons gambeli*) 3
Bean goose (*Anser fabalis*) 2
Pink-footed goose (*Anser brachyrhynchus*) 2
Bar-headed goose (*Eulabia indica*) 2
Canada goose (*Branta canadensis*) 8
Hutchins's goose (*Branta canadensis hutchinsii*) 6
White-cheeked goose (*Branta canadensis occidentalis*) 12
Cackling goose (*Branta canadensis minima*) 2
Brant (*Branta bernicla glaucogastra*) 8
Barnacle goose (*Branta leucopsis*) 5
Spur-winged goose (*Plectropterus gambensis*) 1
Muscovy duck (*Cairina moschata*) 1
Pied goose (*Anseranas semipalmata*) 2
Black-bellied tree duck (*Dendrocygna autumnalis*) 5
Eyton's tree duck (*Dendrocygna eytoni*) 4
Mute swan (*Cygnus gibbus*) 4
Trumpeter swan (*Olor buccinator*) 1
Black swan (*Chenopsis atrata*) 2

FALCONIFORMES

California condor (*Gymnogyps californianus*) 3
Turkey vulture (*Cathartes aura*) 3
Black vulture (*Coragyps urubu*) 1
King vulture (*Sarcoramphus papa*) 2
Secretary bird (*Sagittarius serpentarius*) 1
Griffon vulture (*Gyps fulvus*) 1
African black vulture (*Torgos tracheliotus*) 1
Cinereous vulture (*Ægypius monachus*) 2
Caracara (*polyborus cheriway*) 4
Wedge-tailed eagle (*Uroaëtus audax*) 2
Golden eagle (*Aquila chrysaëtos*) 5
White-bellied sea eagle (*Cuncuma leucogaster*) 2
Bald eagle (*Haliæetus leucocephalus*) 10
Alaskan bald eagle (*Haliæetus leucocephalus alascanus*) 2
Bateleur eagle (*Helotarsus ecaudatus*) 1
Broad-winged hawk (*Buteo platypterus*) 1
Red-tailed hawk (*Buteo borealis*) 7
Pigmy falcon (*Poliohierax semitorquatus*) 1
Sparrow hawk (*Falco sparverius*) 4

GALLIFORMES

Razor-billed curassow (*Mitu mitu*) 4
Penelope (*Penelope boliviana*) 1
Wild turkey (*Meleagris gallopavo silvestris*) 1
Vulturine guinea fowl (*Acryllium vulturinum*) 2
Peafowl (*Pavo cristatus*) 18
Peacock pheasant (*Polyplectron bicalcaratum*) 1
Silver pheasant (*Gennæus nycthemerus*) 2
Lady Amherst's pheasant (*Chrysolophus amherstiæ*) 1
Ring-necked pheasant (*Phasianus torquatus*) 10
European quail (*Coturnix coturnix*) 3
Hungarian quail (*Perdix perdix*) 1
Gambel's quail (*Lophortyx gambelii*) 1
Valley quail (*Lophortyx californica vallicola*) 1
Chukar partridge (*Caccabis chukar*) 2
Scaled quail (*Callipepla squamata*) 5
Massena quail (*Cyrtonyx montezumæ*) 1

GRUIFORMES

East Indian gallinule (*Porphyrio calrus*) 2
Pukeko (*Porphyrio stanleyi*) 1
Black-tailed moor-hen (*Microtribonyx ventralis*) 2
American coot (*Fulica americana*) 1
South Island weka rail (*Ocydromus australis*) 3
Short-winged weka (*Ocydromus brachypterus*) 2
Sandhill crane (*Grus mexicana*) 3
Little brown crane (*Grus canadensis*) 4
Sarus crane (*Grus collaris*) 1
White-necked crane (*Grus leucauchen*) 1
Indian white crane (*Grus leucogeranus*) 1
Lilford's crane (*Grus lilfordi*) 2
Australian crane (*Grus rubicunda*) 2
Demoiselle crane (*Anthropoides virgo*) 6
Crowned crane (*Balearica pavonina*) 1
Kagu (*Rhynochetos jubatus*) 2

CHARADRIIFORMES

Ruff (*Philomachus pugnax*) 4
Lapwing (*Vanellus vanellus*) 1
Yellow-wattled lapwing (*Lobivanellus indicus*) 1
South American stone plover (*Œdicnemus bistriatus vocifer*) 2

Pacific gull (*Gabianus pacificus*) 1
Great black-backed gull (*Larus marinus*) 4
Herring gull (*Larus argentatus*) 3
Silver gull (*Larus novæhollandiæ*) 21
Laughing gull (*Larus atricilla*) 2
Crowned pigeon (*Goura coronata*) 3
Victoria crowned pigeon (*Goura victoria*) 1
Australian crested pigeon (*Ocyphaps lophotes*) 3
Bronze-wing pigeon (*Phaps chalcoptera*) 2
Marquesan dove (*Gallicolumba rubescens*) 7
Bleeding-heart dove (*Gallicolumba luzonica*) 2
Wood pigeon (*Columba palumbus*) 7
Mourning dove (*Zenaidura macroura*) 1
White-fronted dove (*Leptotila fulviventris brachyptera*) 4
Ruddy quail-dove (*Oreopeleia montana*) 1
Necklaced dove (*Spilopelia tigrina*) 4
Zebra dove (*Geopelia striata*) 3
Bar-shouldered dove (*Geopelia humeralis*) 1
Inca dove (*Scardafella inca*) 1
Cuban ground dove (*Chæmepelia passerina aflavida*) 1
Green-winged dove (*Chalcophaps indica*) 1
Ringed turtledove (*Streptopelia risoria*) 3
Fruit pigeon (*Lamprotreron superba*) 1

PSITTACIFORMES

Kea (*Nestor notabilis*) 3
Musk lorikeet (*Glossopsitta concinna*) 1
Cockateel (*Calopsitta novæhollandiæ*) 2
Roseate cockatoo (*Kakatoe roseicapilla*) 15
Bare-eyed cockatoo (*Kakatoe gymnopis*) 1
Leadbeater's cockatoo (*Kakatoe leadbeateri*) 2
Philippine cockatoo (*Kakatoe hæmaturopygia*) 1
White cockatoo (*Kakatoe alba*) 1
Sulphur-crested cockatoo (*Kakatoe galerita*) 9
Great red-crested cockatoo (*Kakatoe moluccensis*) 1
Cassin's macaw (*Ara auricollis*) 1
Mexican green macaw (*Ara mexicana*) 2
Severe macaw (*Ara severa*) 1
Blue-and-yellow macaw (*Ara ararauna*) 7
Red-and-blue-and-yellow macaw (*Ara macao*) 7
Hahn's macaw (*Diopsittaca hahni*) 1
White-eyed paroquet (*Aratinga leucophthalmus*) 1
Petz's paroquet (*Eupsittula canicularis*) 6
Golden-crowned paroquet (*Eupsittula aurea*) 3
Weddell's paroquet (*Eupsittula weddellii*) 3
Blue-winged parrotlet (*Psittacula passerina*) 14
Golden paroquet (*Brotogeris chrysosema*) 2
Tovi paroquet (*Brotogeris jugularis*) 7
Orange-winged paroquet (*Brotogeris chiriri*) 3
Yellow-naped parrot (*Amazona auropalliata*) 3
Mealy parrot (*Amazona farinosa*) 2
Orange-winged parrot (*Amazona amazonica*) 5
Blue-fronted parrot (*Amazona æstiva*) 2
Red-crowned parrot (*Amazona viridigenalis*) 3
Double yellow-headed parrot (*Amazona oratrix*) 9
Yellow-headed parrot (*Amazona ochrocephala*) 4
Festive parrot (*Amazona festiva*) 3
Lesser white-fronted parrot (*Amazona albifrons nana*) 1
Santo Domingo parrot (*Amazona ventralis*) 3
Cuban parrot (*Amazona leucocephala*) 3
Maximilian's parrot (*Pionus maximiliani*) 1
Dusky parrot (*Pionus fuscus*) 2
Blue-headed parrot (*Pionus menstruus*) 2
Amazonian caique (*Pionites xanthomeria*) 5
Lesser vasa parrot (*Coracopsis nigra*) 1
Greater vasa parrot (*Coracopsis vasa*) 1
Red-faced love bird (*Agapornis pullaria*) 8
Pennant's paroquet (*Platycercus elegans*) 2
Rosella paroquet (*Platycercus eximius*) 1
Black-tailed paroquet (*Polytelis melanura*) 1
King paroquet (*Aprosmictus cyanopygius*) 1
Crimson-winged paroquet (*Aprosmictus erythropterus*) 1
Ring-necked paroquet (*Conurus torquatus*) 1
Nepalese paroquet (*Conurus nepalensis*) 1
Philippine green parrot (*Tanygnathus lucionensis*) 1
Grass paroquet (*Melopsittacus undulatus*) 16

CUCULIFORMES

Turaco, immature (*Turacus sp.*) 2

CORACIIFORMES

Giant kingfisher (*Dacelo gigas*) 1
Yellow-billed hornbill (*Lophoceros leucomelas*) 1
Morepork owl (*Spiloglaux novæseelandiæ*) 1
Barred owl (*Strix varia*) 6
Florida barred owl (*Strix varia alleni*) 1
Snowy owl (*Nyctea nyctea*) 1

Screech owl (*Otus asio*)	4
Great horned owl (*Bubo virginianus*)	7
Eagle owl (*Bubo bubo*)	1
American barn owl (*Tyto perlata pratincola*)	5

PASSERIFORMES

Cock-of-the-rock (*Rupicola rupicola*)	1
Silver-eared hill-tit (*Mesia argentauris*)	1
Red-billed hill-tit (*Liothrix luteus*)	11
Black-gorgeted laughing-thrush (*Garrulax pectoralis*)	2
White-eared bulbul (*Otocompsa leucotis*)	3
Red-eared bulbul (*Otocompsa jocosa*)	2
European blackbird (*Turdus merula*)	1
Mockingbird (*Mimus polyglottos*)	1
Piping crow-shrike (*Gymnorhina tibicen*)	2
European raven (*Corvus corax*)	1
American raven (*Corvus corax sinuatus*)	3
Australian crow (*Corvus coronoides*)	1
American crow (*Corvus brachyrhynchos*)	2
Yucatan jay (*Cissilopha yucatanica*)	1
Blue jay (*Cyanocitta cristata*)	2
Green jay (*Xanthoura luxuosa*)	3
Yellow-headed marsh bird (*Agelaius icterocephalus*)	1
Australian gray jumper (*Struthidea cinerea*)	1
Starling (*Sturnus vulgaris*)	9
Shining starling (*Lamprocorax metallicus*)	2
Laysan finch (*Telespyza cantans*)	2
Blue honey creeper (*Cyanerpes cyaneus*)	1
Blue-winged tanager (*Tanagra cyanoptera*)	1
Blue tanager (*Thraupis cana*)	1
Giant whydah (*Diatropura progne*)	3
Paradise whydah (*Steganura paradisea*)	2
Shaft-tailed whydah (*Tetrænura regia*)	1
Napoleon weaver (*Pyromelana afra*)	1
Red-billed weaver (*Quelea quelea*)	1
Bobolink (*Dolichonyx oryzivorus*)	1
Madagascar weaver (*Foudia madagascariensis*)	1
St. Helena waxbill (*Estrilda astrilda*)	4
Rosy-rumped waxbill (*Estrilda rhodopygia*)	1
Nutmeg finch (*Munia punctulata*)	3
White-headed nun (*Munia maja*)	2
Black-headed nun (*Munia atricapilla*)	5
Chestnut-breasted finch (*Munia castaneithorax*)	3
Java finch (*Munia oryzivora*)	13
Masked grassfinch (*Poëphila personata*)	5
Black-faced Gouldian finch (*Poëphila gouldiæ*)	1
Red-faced Gouldian finch (*Poëphila mirabilis*)	1
Diamond finch (*Steganopleura guttata*)	5
Zebra finch (*Tæniopygia castanotis*)	15
Cutthroat finch (*Amadina fasciata*)	9
Red-headed finch (*Amadina erythrocephala*)	2
Hooded oriole (*Icterus cucullatus*)	2
Yellow-tailed oriole (*Icterus mesomelas*)	1
Purple grackle (*Quiscalus quiscula*)	2
Greenfinch (*Chloris chloris*)	3
European goldfinch (*Carduelis carduelis*)	4
Bramble finch (*Fringilla montifringilla*)	4
Yellowhammer (*Emberiza citrinella*)	1
House finch (*Carpodacus mexicanus frontalis*)	2
San Lucas house finch (*Carpodacus mexicanus ruberrimus*)	2
Canary (*Serinus canarius*)	19
Gray singing finch (*Serinus leucopygius*)	9

REPTILES

Alligator (*Alligator mississippiensis*)	43
Water dragon (*Physignathus lesueurii*)	1
Horned toad (*Phrynosoma cornutum*)	2
Glass snake (*Ophisaurus ventralis*)	1
Gila monster (*Heloderma suspectum*)	6
Gould's monitor (*Varanus gouldii*)	1
Philippine monitor (*Varanus salvator*)	1
Blue-tongued lizard (*Tiliqua scincoides*)	1
Rock python (*Python molurus*)	2
Regal python (*Python reticulatus*)	1
Anaconda (*Eunectes murinus*)	2
Boa constrictor (*Constrictor constrictor*)	1
Black snake (*Coluber constrictor*)	2
Blue racer (*Coluber constrictor flaviventris*)	6
Coachwhip snake (*Coluber flagellum*)	2
Chicken snake (*Elaphe quadrivittata*)	1
Corn snake (*Elaphe guttata*)	2
Pilot blacksnake (*Elaphe obsoleta*)	1
Pine snake (*Pituophis melanoleucus*)	4
Bull snake (*Pituophis sayi*)	4
Western bull snake (*Pituophis catenifer*)	1
Water snake (*Natrix sipedon*)	2
Western water snake (*Natrix sipedon fasciata*)	1
Garter snake (*Thamnophis sirtalis*)	1
Florida rattlesnake (*Crotalus adamanteus*)	3
Western diamond rattlesnake (*Crotalus atrox*)	4
Snapping turtle (*Chelydra serpentina*)	5
Florida snapping turtle (*Chelydra osceola*)	1
Rossignon's snapping turtle (*Chelydra rossignonii*)	1
Musk turtle (*Kinosternon odoratum*)	1
Mexican musk turtle (*Kinosternon sonoriense*)	1

South American musk turtle (*Kinosternon scorpioides*)	5	Gopher tortoise (*Gopherus polyphemus*)	2
Pennsylvania musk turtle (*Kinosternon subrubrum*)	2	Duncan Island tortoise (*Testudo ephippium*)	1
Wood turtle (*Clemmys insculpta*)	1	Indefatigable Island tortoise (*Testudo porteri*)	1
European pond turtle (*Emys orbicularis*)	5	Albemarle Island tortoise (*Testudo vicina*)	2
South American terrapin (*Nicoria punctularia*)	1	South American tortoise (*Testudo denticulata*)	2
Reeves turtle (*Geoclemmys reevesi*)	1	African tortoise (*Testudo hermanni*)	1
Painted turtle (*Chrysemys picta*)	3	Long-necked turtle (*Chelodina longicollis*)	1
Cooter (*Pseudemys scripta*)	2	Chicken turtle (*Deirochelys reticularia*)	1
Central American cooter (*Pseudemys ornata*)	2		

Statement of the collection

	Mammals	Birds	Reptiles	Total
Presented	28	54	34	116
Born and hatched in National Zoological Park	54	20		74
Received in exchange	2	12		14
Purchased	60	26	5	91
Transferred from other Government departments	1	11	1	13
Deposited	15	13	6	34
	160	136	46	342

SUMMARY

Animals on hand July 1, 1924	1,645
Accessions during the year	342
Total animals handled	1,987
Deduct loss (by death, return of animals, and exchange)	367
	1,620

Status of collection

	Species	Individuals
Mammals	178	503
Birds	285	982
Reptiles	48	135
Total	511	1,620

Compared with the previous year, a decrease in number of individuals is shown and compared with 1923, when there were 1,768 animals in the collection, a still greater decrease is noted. This is due to continued losses in the aging stock, especially among the larger forms. The number of forms represented exceeds that of last year, an increase due to judicious selection and purchase of small species offered at moderate prices.

Additional funds are urgently needed for purchase of animals to fill the steadily increasing gaps in the groups of larger mammals.

VISITORS

The attendance record as determined by count and estimate exceeded that of the previous year by 75,385. The greatest attendance for one month was 372,950, in April. The increase is highly gratifying as it indicates the keen interest of the general public in the collections.

The attendance by months was as follows:

July	240,700
August	324,000
September	232,725
October	235,000
November	179,500
December	56,630
January	37,110
February	121,550
March	248,200
April	372,950
May	269,300
June	200,600
Total for year	2,518,265

Schools, classes, and similar organizations, recorded among the visitors, number 266, with a total of 20,890 individuals.

The highest attendance for a year recorded previously was 2,444,880 in 1924.

IMPROVEMENTS

The animal warehouse, 24 by 90 feet, with a small ell for a feed room, the construction of which had been begun during the previous year, was completed and put into service before the end of 1925. This building is very useful, both as quarters for animals temporarily not on exhibition, and as a reception house for animals just arriving where they may rest before being placed on exhibition. It will also be useful during the winter in storing birds which are exhibited during the summer in the big flight cage and elsewhere, and for which there is no room in the bird house.

A double bear cage of steel, each half 12 by 16 feet, with concrete shelter, has been erected to take the place of a large wooden cage that was decayed beyond safety or justifiable repair.

The log dam of loose bowlders across Rock Creek at the head of the American water-fowl pond to maintain a flow of water into the pond, which had been repeatedly washed out by floods, was replaced by a log dam faced with bowlders. The logs used were obtained from chestnut trees in the park that had died from bark disease.

A concrete chimney was built on the restaurant. This building still needs various improvements, especially the addition of a kitchen,

as well as an inclosed room where visitors may lunch comfortably in cold weather.

The bird house required repairs, as usual. Some of the cages were in such bad condition that they had to be entirely replaced. A new floor was laid in the feed room, and various minor repairs made. The roof leaked badly and will require treatment during the coming year.

The eland house, the zebra house, the fences about these, rubbish containers, outdoor benches, various inclosure fences, and other ironwork were painted during the year.

WATER MAIN

One thousand five hundred and eighty feet of six-inch water main was laid, and two fire hydrants installed, through a special appropriation of $3,250, supplemented by funds taken from the general appropriation.

NEEDS OF THE PARK

The need of the park for exhibition buildings is even more acute than in previous years, as there has been tremendous growth in the number of visitors and there is need for better conditions for exhibition. The most important and customary buildings required by a zoological park are: Carnivore, pachyderm, primate, antelope, small mammal, bird, and reptile houses. Of permanent structures, the National Zoological Park has a primate house, a house to contain one elephant, and one end of a carnivore house. All other buildings are old, without exception originally built as temporary makeshifts and kept together only by continual and often expensive repairs.

The building that shelters most of the birds, built 28 years ago, was then intended to house the collections for three or four years, until a suitable bird house could be constructed. This structure is dark, with walls so decayed that they will no longer hold pebble-dash, and provides entirely inadequate space for either the collection of birds or the great numbers of visitors; it is not only unfit for its present use but actually unsafe for its inmates.

There is no house for reptiles, always popular with visitors, and none for small mammals. Such reptiles and small mammals as are shown at the park are scattered about in places where it is inconvenient to care for them, and where in some instances they actually close the passages needed for visitors.

During a period of 35 years a collection of animals has been assembled in the National Zoological Park which ranks among the most notable in this country. Adequate buildings to replace the

present obsolete quarters should be provided to house properly the living animals, to maintain them in health, and to exhibit them to the more than two million visitors who come annually to view them.

FUNDS FOR THE PURCHASE OF ANIMALS

The collection at the National Zoological Park is augmented each year by various gifts, and through unusual success in the breeding and rearing of animals, the park has been able to exchange specimens with other zoological parks so that it has maintained a reasonably well-balanced collection of the living animals of the world, always lacking, however, representatives of certain important and interesting species. For instance, there has never been a giraffe at the park. There is no rhinoceros, no pigmy hippopotamus, and no Indian elephant. Such animals as these, when offered to the park can not be considered owing to the entirely inadequate fund for the purchase of animals, and opportunities are frequently lost to fill definite gaps in the collection, as well as to replace species lost through death, by the purchase of most desirable animals that are offered for sale.

An increased appropriation to cover cost and transportation of animals has been requested, but it seems advisable also to repeat the suggestion made in previous reports that an animal purchase fund be inaugurated and deposited with the Smithsonian Institution.

REVENUES OF THE PARK

A zoological park itself is not expected to finance the refreshment of visitors. There are in the National Zoological Park, however, as in other parks, a refreshment stand and a restaurant which are rented to private parties. The money from these concessions, under present regulations, goes to the United States Treasury and can not be used for the park, although repairs and other costs in connection with the restaurant must be borne by the park. It is earnestly recommended that the revenues from the restaurant concession, which serves only to benefit the public, be turned into the animal fund of the park instead of into the general fund of the Treasury. Such is the established practice in other parks, municipal and otherwise, which often derive considerable funds for the purchase of animals from such concessions.

Respectfully submitted.

W. M. Mann, *Superintendent.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 7

REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: The Astrophysical Observatory was conducted under the following passage of the independent offices appropriation act approved June 7, 1924:

> Astrophysical Observatory: For maintenance of the Astrophysical Observatory, under the direction of the Smithsonian Institution, including assistants, purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, repairs and alterations of buildings, and miscellaneous expenses, $21,580.

The observatory occupies a number of frame structures within an inclosure of about 16,000 square feet south of the Smithsonian administration building at Washington, a cement observing station and frame cottage for observers on a plot of 10,000 square feet leased from the Carnegie Solar Observatory on Mount Wilson, Calif., and also a solar observing station on Mount Harqua Hala, Ariz., erected in 1920 at the expense of private funds contributed by Mr. John A. Roebling, of Bernardsville, N. J.

The present value of the buildings and equipment for the Astrophysical Observatory owned by the Government is estimated at $50,000. This estimate contemplates the cost required to replace the outfit for the purposes of the investigation.

WORK OF THE YEAR

Solar variation and forecasting.—The chief object of the work at present is to secure the most exact measurements of the variation of the sun in order to provide proper data for studying the influence of solar changes on weather conditions of the United States and the whole world. Accordingly, the efforts of the staff were devoted mainly to this purpose. The Government appropriations were sufficient only to maintain the work at Washington and Arizona, and to pay salaries of two observers at the exceptionally favorable station at Montezuma, Chile. This station was established in 1918, and has been maintained ever since by private funds of the Institution, supplemented by gifts of Mr. Roebling. Owing to further support by Mr. Roebling, it has been possible to receive daily telegrams reporting the solar radiation observations in Chile and in Arizona. These arrive at Washington within 24 hours of the observations in the field.

The experimental forecasts by Mr. H. H. Clayton for the city of New York, mentioned in last year's report, were continued. For this purpose daily telegrams of the condition of the sun were sent from Washington to Mr. Clayton at Canton, Mass. These usually reached him before noon on the day after the observations were made in Chile and Arizona. Making up his New York forecasts for three, four, and five days ahead, Mr. Clayton informed the Smithsonian by letter on the same afternoon. On Friday of each week he forecast the temperature departures for the ensuing week beginning Sunday, and about the end of each month he forecast the temperature departures for the ensuing month. These weekly and monthly forecasts were also mailed in advance to the Smithsonian Institution.

We have compared Clayton's forecasts with the events, using mathematical processes of verification which are not susceptible of personal bias. A moderate degree of foreknowledge is certainly indicated, both for the specific forecasts of three, four, and five days in advance, and for the more general average forecasts of weeks and months.

On May 2, 1925, a symposium on this subject was held at the United States Weather Bureau before the American Meteorological Society. At that time, Messrs. C. G. Abbot and H. H. Clayton explained the status of the measurements of solar variation, and their applications for forecasting. Later, these papers of Abbot and Clayton, and also a paper by Mr. G. Hoxmark, on the results reached since 1922 in the application of solar variation for official forecasts in Argentina, were published as Nos. 5, 6, and 7, of Volume 77, Smithsonian Miscellaneous Collections.

The costs of telegraphic advices and of Mr. Clayton's computing bureau have been borne by Mr. Roebling's gifts for these purposes, as also the cost of publication of the papers just mentioned.

No public forecasts have been made or will be made under the auspices of the Smithsonian Institution. Our entire purpose in the matter is, and has always been, to make such experiments as might indicate what value, if any, would attach to the introduction of a new variable, namely, the variation of the sun, in weather forecasting. Our forecasts are made privately and only as tests of the experimental conclusions.

Unfortunately, space writers in the public prints have not understood this and have attributed to the Smithsonian Institution forecasts of weather conditions far into the future. These, in reality, have been made by several private individuals entirely unconnected with the Institution. We take no responsibility for these prognostications, as we know as yet of no sound method by which they may be made.

A compilation of all results on the solar constant of radiation, from 1918 to November, 1924, was published as No. 3 of Volume 77, Smithsonian Miscellaneous Collections.

The investigations hitherto made having indicated that a higher degree of accuracy in our solar measurements is needed to supply proper data for forecasting purposes, a very great deal of attention has been given to the elimination of small sources of error in the observations and reductions of solar radiation. Already the average deviation of individual days' results between Chile and Arizona is but one-half per cent. It follows that in order to attain higher accuracy we shall be obliged to regard sources of error which formerly we supposed would always be negligible.

This has led to the designing and construction of new apparatus for use in pyrheliometry, which eliminates the employment of the observer's watch altogether. It has also required the investigation of the infra-red and ultra-violet portions of the solar spectrum, beyond the usual limits of our daily spectrum observations. Still more important, it has led to a complete revision of the methods of measuring and reducing solar energy spectra. With these new modifications in mind, a complete re-reduction of all solar radiation work since the beginning of the year 1922 has been undertaken, and occupies the whole force at Washington.

Removal of Mount Harqua Hala station.—The station at Mount Harqua Hala, Ariz., first occupied in 1920, proves to be too far to the east, so that the summer months there are unsuitable for observing, because of the atmospheric conditions which go to bring about the severe thunderstorms of Arizona. Very few days of June, July, and August have been suitable for our exacting work, and even some of the spring months have been marred by long-continued haziness. Had weather conditions there been first-rate, the observers would gladly have suffered the excessive isolation of the place, which is almost wholly cut off from relaxations, but to make such a sacrifice fruitlessly is indeed very depressing.

Accordingly, investigations have been made which have fixed on a better site, both as regards weather conditions and comfort. This is chosen on Table Mountain, within the bounds of the Los Angeles County Park, about 30 miles northeast of Mount Wilson. Lying on the edge of the Mojave Desert, at 7,500 feet elevation, the weather observations indicate very decided improvement over Harqua Hala for our purpose. Add to this the convenience of access and pleasant surroundings and we have combined there great advantages.

Mr. John A. Roebling has added to his already great gifts sufficient means to enable necessary buildings to be erected on Table Mountain, and to remove the observing outfit thence from Harqua

Hala. The supervisors of the Los Angeles County Park have cordially assisted in the transfer, giving rights of occupancy, and extending the auto road quite to the doors of the proposed observatory, without expense to the Smithsonian Institution. It is expected to occupy Table Mountain beginning about October 1, 1925. Mr. Moore's energetic efforts in the preliminary arrangements and the preparation of buildings deserve high praise.

An expedition under Doctor Abbot occupied Mount Wilson in the summer and autumn of 1924. The solar cooker was rebuilt, as far as concerned its oven, its circulatory system for hot oil, and its insulation against heat losses. The new oil system was perfectly successful in avoiding all leaks, such as always hitherto have marred the operations. Also, the introduction of a larger reservoir, and especially of "Silocel," or diatomaceous bricks, for heat insulation proved highly satisfactory. The experiment was tried of introducing forced oil circulation by means of a little steam engine operated by the heat of the reservoir. This worked well mechanically, but proved unnecessary, as no higher temperatures of the oven were reached when forced circulation was in operation.

It was intended to use a vacuum jacket about the heater tube, but the apparatus was not received in season. Without this crowning improvement the solar cooker worked fully as well as in 1920, when its reputation was first made, despite the fact that somewhat thicker insulation of the reservoir is needed, as the cooling curve shows. When this, and also the vacuum jacket, are applied, the machine should be highly satisfactory.

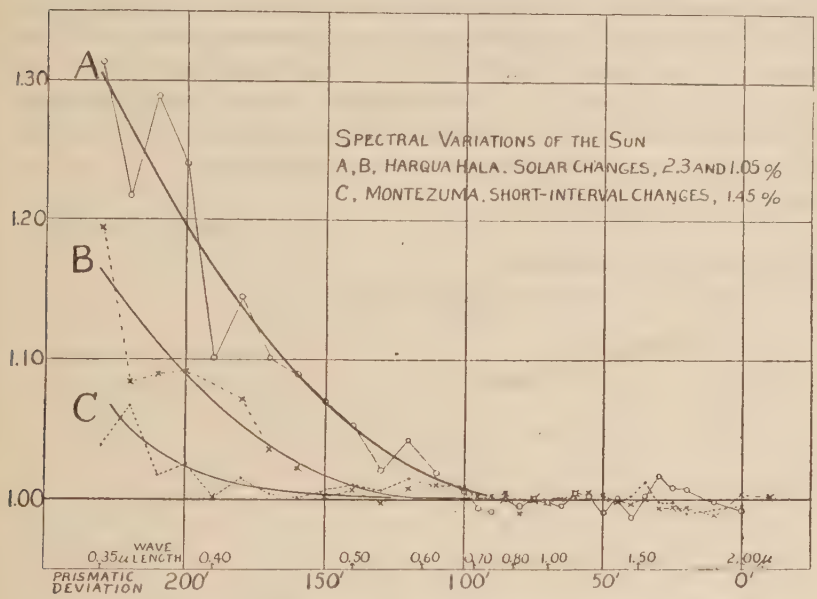
As noted in last year's report, the Fabry type of apparatus has been installed on Mount Wilson to measure the quantity of atmospheric ozone. This feeble constituent of the very high air is, we believe, very important in the economy of the earth's heat, as well as a fatal bar to observation of the most interesting part of the spectra of the sun and the hotter stars.

Having fully developed and tested the ozone outfit, photographic solar spectra of the ozone-absorption region of the ultra-violet were obtained in August, September, and October, 1925. Unfortunately the great forest fire east of Mount Wilson cut off a good many otherwise favorable days. By the generosity of Mr. Roebling a copy of the Moll spectrophotometer for measuring the plates has been procured from A. Hilger. The reductions are not yet made. Mr. Roebling's interest in this ozone research is so great that he has made a grant to enable Doctor Fabry himself to continue daily ozone measurements in France during a part of the year 1925.

The importance of studies of the variation of the sun's output of ultra-violet rays grows upon our attention. Not only the attack

on the ozone problem in that spectral region, but also the extraordinary relations of the ultra-violet rays to human, animal, and plant physiology are coming increasingly to the fore. Our own studies indicate that the solar variations are far greater for those rays than they are for the solar rays as a whole. Thus the accompanying figure indicates that when the solar constant of radiation changes by 1 per cent it means almost imperceptible change for the infra-red rays, but as much as 10 per cent or more for some rays of the ultra-violet.

In addition to the work at Mount Wilson on the solar cooker and the ozone of the higher atmosphere, much attention was paid to



Solar variation localized in the violet and ultra-violet

attempts to improve the radiometer and the stellar-spectrum apparatus, in the hope of going much further in studying the energy spectra of the stars. Much knowledge was gained which will be useful later on, and star-spectrum observations were made on several nights, but no actually completed advance in stellar spectra was attained. The way, however, is very clear now for future advance.

PERSONNEL

Mr. H. B. Freeman accepted service on the private Smithsonian roll as assistant at Harqua Hala in September, 1924, and succeeded Mr. L. B. Aldrich in charge at Montezuma on March 1, 1925. Mr. Aldrich returned to Washington.

Mr. E. E. Smith was employed on the private roll as assistant at Harqua Hala from February 9, 1925.

Mr. A. J. Ahearn assisted Doctor Abbot on Mount Wilson during the expedition of 1924.

SUMMARY

Much progress in the study of the variation of the sun and its application to weather forecasting has been made, as reported in publications Nos. 5, 6, and 7 of Volume 77, Smithsonian Miscellaneous Collections. Improvements in apparatus and methods designed to add to the accuracy of solar radiation measurements, and to make possible a valuable revision of existing values, are on foot. The station at Harqua Hala, having proved somewhat disappointing, is being removed to Table Mountain, in California, about 2,000 feet higher, but much more accessible. The solar cooker has been greatly improved. Measurements of atmospheric ozone are in progress. New devices were tried in stellar energy spectrum measurements and the way seems clear for great advances in that line.

Respectfully submitted.

C. G. Abbot, *Director.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 8

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

SIR: I have the honor to submit the following report on the operations of the United States Regional Bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1925:

As has been stated in previous annual reports, actual publication of the catalogue was suspended in 1921 upon completion of the fourteenth annual issue. In conformity with an agreement reached at the International Convention held in Brussels in 1922, the work of this regional bureau, in common with others of the organization, has been continued but is confined to the collection of the data necessary to index the current scientific literature of the United States for the several years intervening between the cessation of publication and the present time. This procedure not only enables the organization to be kept intact but, when publication is resumed and the classification schedules are revised, data will be available to complete the catalogue.

It seems advisable to again outline the aim, scope, and need of the catalogue in view of the fact that the many new projects which have sprung up in minor fields, lacking harmony of purpose and cooperation of effort, have, even when taken collectively, entirely failed to supply the need of an International Catalogue of Scientific Literature.

The catalogue was started in 1901 with the aim and purpose of meeting the long-felt need of scientific investigators and librarians for an annual authors' and subject catalogue and index to the scientific literature of the world, a need felt even more to-day than in 1901. To this end, systematic classification schedules were prepared covering all recognized branches of science and each paper was not only catalogued and indexed, but also classified by means of these schedules, the result being equivalent to an analytical digest of each paper.

Financial support to enable the organization to properly function is urgent. The amount required is not great, measured in present-day terms, but is none the less essential. Between 1901 and the beginning of the war, necessary funds for publication were supplied by subscribers in the countries taking part in the enterprise. Only the actual cost of printing and publishing had to be met from these

funds as maintenance of the several regional bureaus was then, as now, provided for, in most cases, by direct governmental grants. However, the additional funds needed to meet the increased cost of printing and publishing, under war conditions, had to be met by the subscribers and these increases when expressed in the depreciated currency of many countries, resulted in impossible figures; consequently, publication had to be suspended.

When operations began in 1901, the price to subscribers of a complete set of the 17 annual volumes of the catalogue, comprising about 10,000 pages, was £17, the pound sterling being then at par. The American subscription price was, after adding shipping costs, $85. The income derived from subscriptions and the expenditures of the London Central Bureau, in charge of printing and publishing, approximately balanced in 1914, when war began. Since that time publishing costs, in England, have doubled and the value of the French franc has sunk to less than one-fourth, and the Italian lira to less than one-fifth of their respective par values. Without tabulation, it is obvious that a cost easily borne in these countries in 1901 has become impossible in 1925. It was never the intention for the International Catalogue to be a commercial enterprise, but rather the means of furnishing, at cost, to investigators and students data needed to keep them informed of the scientific progress of the world. Experience proves that international cooperation is the only means whereby the necessary data can be collected and prepared for such an index, but it is now apparent that some new source of revenue must be provided to print this data before publication can be resumed.

Could a sufficient endowment be obtained, the organization would again become self-supporting, as there is now a greater demand for the catalogue than ever before and a central bureau provided with its own publishing plant, or capital sufficient to make advantageous long-term contracts with properly equipped publishing houses, would be enabled to offset the increased cost of publication by the saving of the interest and other charges, which were necessary in 1901 to an organization doing business without capital. If it were possible to secure such an endowment in the United States, now the only country not unduly oppressed by the results of war, American students and investigators would be much benefited for, notwithstanding impoverished conditions, much advanced and valuable scientific work is being done abroad with which it is difficult to keep in touch without the annual volumes of the International Catalogue.

Respectfully submitted.

LEONARD C. GUNNELL,
Assistant in Charge.

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 9

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the library of the Smithsonian Institution for the fiscal year ended June 30, 1925.

CHANGES IN STAFF

During the year there were several changes in the library staff. Mr. Paul Brockett, who had been connected with the Smithsonian Institution for 38 years and had served since 1902 as its assistant librarian, resigned to devote full time to his duties as assistant secretary of the National Academy of Sciences. Mr. Brockett's successor, Mr. William L. Corbin, formerly professor of English in Boston University, assumed the position of librarian on September 15.

Mr. Newton P. Scudder, assistant librarian of the United States National Museum, retired from active service March 9, on account of age and disability, and died May 19. Mr. Scudder became connected with the Smithsonian Institution in 1882, where he remained for more than 40 years, the last 38 of which he was assistant librarian of the National Museum. Perhaps never again will the Museum library have as its reference chief a person so fully acquainted with its collections as he was, or so willing to give of his knowledge and time to those who came with questions.

Mr. Lester D. Condit, assistant in the library since 1918, was granted a furlough in October to resume his university course. He has since withdrawn from the library staff and the position was filled by the appointment of Miss Sara L. Young, a graduate of Elmira College and of Drexel Institute Library School. Miss Young has worked with scientific publications for many years, especially as cataloguer for the American Philosophical Society and the Library of Congress.

EXCHANGE OF PUBLICATIONS

The increase of the Smithsonian Library is due chiefly to the exchange of publications between the Smithsonian Institution and other learned institutions and societies of the world. Many of

these publications come to the library direct, others through the International Exchange Service, with which the library is in close cooperation. During the past year the library received 30,496 packages by mail and 2,408 through the exchanges. Especially large sendings were received from Barcelona, Budapest, and Warsaw. As usual, after these packages had been opened, the items were stamped, entered, and sent to the appropriate branches of the library. The large number received was due partly to the special effort made by the periodical and correspondence divisions in noting wants and writing follow-up letters. In fact, most of the 1,181 letters sent out by the library had to do with these wants. The result was that of the 2,478 missing volumes and parts requested, 2,009 were obtained, a gain of nearly 30 per cent over last year. Exchange relations were also opened with a number of new societies.

MAIN LIBRARY

Many of the items mentioned above were, of course, forwarded day by day to the Smithsonian deposit in the Library of Congress, where they were made available to the public. The number of these was 7,287, of which there were 5,184 complete volumes, 1,421 parts of volumes, 390 pamphlets, and 292 charts. Documents of foreign governments, more or less statistical in character, to the number of 7,408, were also sent, without being stamped or entered, to the document division of the Library of Congress.

Dissertations were received from various universities at home and abroad, such as Basel, Berlin, Bern, Breslau, Copenhagen, Cornell, Dresden, Erlangen, Frankfurt a. M., Freiburg, Ghent, Giessen, Greifswald, Halle, Heidelberg, Helsingfors, Leipzig, Leyden, Lund, Marburg, Paris, Pennsylvania, Strasbourg, Tübingen, Uppsala, Utrecht, and Zürich; and from technical schools at Berlin, Delft, Karlsruhe, and Zürich.

OFFICE LIBRARY

The office library, which includes the publications of several learned societies, the aeronautical collection, the art-room collection, the employees' library, and various books, chiefly of a reference nature, in the administrative offices, was increased during the year by 312 volumes, 5 parts of volumes, and 4 pamphlets. Of these, 34 were added to the aeronautical collection.

One of the most important additions to this library was a de luxe copy of the Warner Library of the World's Best Literature, the gift of Secretary Walcott; another was Seven Log-Books Concerning the Arctic Voyages of Capt. William Scoresby, sr., of Whitby, England, presented by the Explorers Club of New York.

The circulation of the library was 2,359, of which 1,956 were magazines borrowed from the reading room. Many more volumes and periodicals were consulted in the reference room. The books most in demand were the transactions of the learned societies, the aeronautical collection, and several important individual works, such as Combarelles aux Ezyies, by Abbé Breuil and others, a book finally assigned to the Smithsonian deposit.

The work done during the year on the general catalogue of the Smithsonian library, which is kept in the office reading room, may be summarized as follows:

Volumes and pamphlets catalogued	4,509
Volumes recatalogued	264
Charts catalogued	324
Cards typed	2,157
Library of Congress cards filed	1,078
New authors added	393

MUSEUM LIBRARY

The library of the United States National Museum contains 65,148 volumes and 102,951 pamphlets, a total of 168,099. Of these, 1,457 volumes and 1,894 pamphlets were added during the year.

While most of these accessions were obtained by exchange of publications, or by purchase, many came by gift. Among the donors were Mr. W. I. Adams, Miss M. D. Ashton, Dr. Marcus Benjamin, Mr. A. H. Clark, Mr. F. W. Clarke, Dr. W. H. Dall, Mr. J. A. Gallagher, Mr. L. C. Gunnell, Dr. O. P. Hay, Dr. W. H. Holmes, Dr. A. Hrdlička, Dr. W. R. Maxon, Dr. G. S. Miller, jr., Mr. W. de C. Ravenel, Dr. C. W. Richmond, Mr. S. A. Rohwer, Mr. E. V. Shannon, Mr. R. C. Smith, Mr. B. H. Swales, and Dr. C. D. Walcott. The gifts of Secretary Walcott to the division of geology and paleontology and of Doctor Dall to that of mollusks were generous, as usual, the latter numbering 97 titles. The gifts of Doctor Richmond to the division of birds were also large. But the outstanding gift of the year was the entomological library, numbering about 4,500 volumes and pamphlets, chiefly on Coleoptera, left to the Museum by the late Col. Thomas L. Casey, and increased by the generosity of Mrs. Casey. This is one of the best collections on its subject in the United States, and contains many rare items. It will be made available to the curators as soon as possible and will be deposited in the section of insects.

In the course of the year several thousand cards of the Concilium Bibliographicum were filed, 14,329 parts of periodicals were entered, 2,623 volumes and pamphlets were catalogued, and 9,000 cards were added. Books borrowed from the Library of Congress numbered 1,628 and from other libraries 112, chiefly for the use of the

curators, and about the same number were returned. The loans totaled 8,148, of which 5,861 were made to the sectional libraries, and more than ever before to universities, such as Chicago, Illinois, Michigan, and Minnesota, and to other institutions, both in Washington and elsewhere. Many publications were consulted in the reference room, not only by members of the Museum staff but also by others, especially Government employees and scholars connected with various universities and museums, American and foreign. Two hundred and fifty-six volumes were bound.

The number of sectional libraries in the Museum is now 38. These, while under the immediate care of the administrative and scientific staffs, are at the same time very real and important parts of the general library and are administered as such. Their resources are its resources, and their needs are its needs. And these needs are often most urgent—the very ones to which the librarian feels he should give his best thought and help. The past year he has devoted much time to the study of these resources and needs, and to the solution of the problems they have disclosed. The sectional libraries are as follows:

Administration.
Administrative assistant's office.
American archeology.
Anthropology.
Biology.
Birds.
Botany.
Echinoderms.
Editor's office.
Ethnology.
Fishes.
Foods.
Geology.
Graphic arts.
History.
Insects.
Invertebrate paleontology.
Mammals.
Marine invertebrates.
Mechanical technology.
Medicine.
Mineral technology.
Minerals.
Mollusks.
National Gallery of Art.
Old World archeology.
Organic chemistry.
Paleobotany.
Photography.
Physical anthropology.
Property clerk's office.
Reptiles and batrachians.
Superintendent's office.
Taxidermy.
Textiles.
Vertebrate paleontology.
War library.
Wood technology.

TECHNOLOGICAL LIBRARY

The technological library, the division of the Museum Library which contains the collections of especial interest to the curators of arts and industries, is located in the Old Museum Building. During the year the reorganization of its material was continued. Its accessions numbered 152 volumes and 353 pamphlets, and its loans 150.

ASTROPHYSICAL OBSERVATORY LIBRARY

Additions to the library of the Astrophysical Observatory numbered 114 volumes, 32 parts of volumes, and 89 pamphlets. The number of volumes bound was 81. Exact records of loans can not be given, as they are included with those of the office library.

This is one of the most important of the smaller branches of the Smithsonian library and is much in use. Thanks to the generosity of a friend, its collections will be enlarged and made more available in the immediate future.

BUREAU OF AMERICAN ETHNOLOGY LIBRARY

The activities of the library of the Bureau of American Ethnology are described in the report of the chief of that bureau, by whom the library is administered.

NATIONAL GALLERY OF ART LIBRARY

As the National Gallery of Art is housed in the Natural History Building, its library is at present administered as a sectional library of the National Museum. This library, although possessing only 961 titles, of which 426 are volumes and 535 pamphlets, has been most carefully selected, and should grow rapidly when given room in the National Gallery Building now in prospect. Its accessions during the year were 118 volumes, 478 parts of volumes, and 52 pamphlets.

FREER GALLERY OF ART LIBRARY

The library of the Freer Gallery of Art is solely a reference library, restricted to the interests represented in the collections of art objects—that is to say, to the arts and cultures of the Far East, of India and Persia, and the nearer east; to the life and works of James McNeill Whistler and of certain other American painters whose pictures are owned by the gallery; and further, to a very limited degree, to that field of study represented by the Biblical manuscripts of the fourth and fifth centuries, which, as the possessions of the Freer Gallery, are known as the Washington manuscripts. All books and library facilities are at the service of the public. During the year 200 persons availed themselves of these privileges. Most of the more serious students came from a distance for the especial purpose of studying various parts of the collections and the books relating to them.

The library comprises about 2,200 books in English, French, German, and Dutch and almost 300 in Chinese, Japanese, and Tibetan, with necessary dictionaries. In addition, there are a good many volumes on loan from the Library of Congress. During the year 90 volumes and 127 pamphlets were added to the library.

NATIONAL ZOOLOGICAL PARK LIBRARY

Early in the year the cataloguing of the library of the National Zoological Park was completed, and its duplicates and other superfluous material were removed. Its accessions, including the old items which had been in the library for some time but which had never been entered, were 475 volumes, 1 part, and 2 pamphlets.

SUMMARY OF ACCESSIONS

The accessions for the year, with the exception of those to the library of the Bureau of American Ethnology, may be summarized as follows:

Library	Volumes	Other publications	Total
Astrophysical Observatory	114	121	235
Freer Gallery of Art	90	127	217
National Gallery of Art	118	530	648
National Zoological Park	475	3	478
Smithsonian deposit, Library of Congress	5,184	2,103	7,287
Smithsonian office	312	9	321
United States National Museum	1,457	1,894	3,351
Total	7,750	4,787	12,537

An estimate of the number of volumes, pamphlets, and charts in the Smithsonian library (including the Smithsonian deposit in the Library of Congress) on June 30, 1925, was as follows:

Volumes	507,750
Pamphlets	137,558
Charts	23,462
Total	668,770

This number does not include the many thousands of parts of volumes now in the library awaiting completion of the volumes.

SPECIAL ACTIVITIES

Besides carrying on the usual work of the year, the library staff gave as much time as possible to special problems, such as sorting accumulations of miscellaneous material in different parts of the library; bringing together superfluous duplicates and separates to be disposed of later by gift or by piece for piece exchange; inventorying the sectional libraries; making shelf lists for the two divisions of the Museum library; advancing the cataloguing of several of the special collections, particularly the Iddings, Gill, and Knab; furthering the cause of science by making part of the Lacoe collec-

tion available for semipermanent deposit with colleges, universities, and museums; and responding to many requests involving reference work for various Government departments and for institutions and individuals the country over.

Furthermore, the librarian made an extensive survey of the condition of the library and submitted a detailed report of its needs to the secretary. This survey revealed many problems pressing for solution, problems that can be solved only by a liberal increase, over a term of years, of the funds appropriated for library purposes. These increased funds should be at hand at the earliest possible moment, to the end that more than 8,000 volumes may be bound; that more than 30,000 books and pamphlets, including several almost priceless collections, may be accessioned and catalogued; that a dictionary catalogue of the entire library (including the sectional libraries), except, of course, the Smithsonian deposit, may be made; and that other urgent pieces of work connected with the reorganization and development of the library may be done—in a word, that the rich collections of the library may, by a more complete application of modern methods, be made available without undue delay to scientific workers, both in Washington and elsewhere. Then and then only will the library be ready to do its full part toward the increase and diffusion of knowledge among men.

Respectfully submitted.

WILLIAM L. CORBIN,
Librarian.

DR. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON THE PUBLICATIONS

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ending June 30, 1925:

The Institution proper published during the year 12 papers in the series of Miscellaneous Collections, 2 annual reports and pamphlet copies of 48 articles in the general appendixes to these reports, and 6 special publications. The Bureau of American Ethnology published 1 bulletin and 2 annual reports. The United States National Museum issued 1 annual report, 2 volumes of proceedings, 2 complete bulletins, 1 part of a bulletin, 3 parts of 2 volumes in the series of Contributions from the United States National Herbarium, and 66 separates from the proceedings. The National Gallery of Art issued four catalogues of special exhibitions.

Of these publications there were distributed during the year 171,865 copies, which included 262 volumes and separates of the Smithsonian Contributions to Knowledge, 24,008 volumes and separates of the Smithsonian Miscellaneous Collections, 26,825 volumes and separates of the Smithsonian annual reports, 6,102 Smithsonian special publications, 104,596 volumes and separates of the various series of National Museum publications, 7,354 publications of the Bureau of American Ethnology, 114 publications of the National Gallery of Art, 68 volumes of the Annals of the Astrophysical Observatory, 44 reports on the Harriman Alaska expedition, 1,057 reports of the American Historical Association, and 1,435 publications presented to but not issued directly by the Smithsonian Institution or its branches.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

Of the Smithsonian Miscellaneous Collections, volume 69, 1 paper was issued; volume 75, 2 papers; volume 76, 3 papers; volume 77, 6 papers; in all, 12 papers, as follows:

VOLUME 69

No. 1. Smithsonian Meteorological Tables, Fourth Revised Edition. First Reprint. December 5, 1924. (Publ. 2493.)

VOLUME 75

No. 2. Cambrian Geology and Paleontology. V. No. 2. Cambrian and Lower Ozarkian Trilobites. By Charles D. Walcott. July 19, 1924. Pp. 53–66, pls. 9–14. (Publ. 2788.)

No. 3. Cambrian Geology and Paleontology. V. No. 3. Cambrian and Ozarkian Trilobites. By Charles D. Walcott. June 1, 1925. Pp. 61–146, pls. 15–24. (Publ. 2823.)

VOLUME 76

No. 11. The Freshfield Glacier, Canadian Rockies. By Howard Palmer. August 2, 1924. 16 pp., 9 pls., 3 text figs. (Publ. 2757.)

No. 12. "Adaptations" to Social Life: The Termites (Isoptera). By Thomas E. Snyder. September 2, 1924. 14 pp., 3 pls. (Publ. 2786.)

No. 13. Preliminary Archeological Explorations at Weeden Island, Florida. By J. Walter Fewkes. October 14, 1924. 26 pp., 21 pls., 1 text fig. (Publ. 2787.)

VOLUME 77

No. 1. A Chapter in the History of Zoological Nomenclature. By Leonhard Stejneger. August 30, 1924. 21 pp. (Publ. 2789.)

No. 2. Explorations and Field Work of the Smithsonian Institution in 1924. April 17, 1925. 136 pp., 138 text figs. (Publ. 2794.)

No. 3 Provisional Solar Constant Values, August, 1920, to November, 1924. By C. G. Abbot and Colleagues. February 17, 1925. 38 pp., 2 text figs. (Publ. 2818.)

No. 5. Solar Variation and Forecasting. By C. G. Abbot. June 20, 1925. 27 pp., 18 figs. (Publ. 2825.)

No. 6. Solar Radiation and Weather, or Forecasting Weather from Observations of the Sun. By H. H. Clayton. June 20, 1925. 64 pp., 45 text figs. (Publ. 2826.)

No. 7. Solar Radiation and the Weekly Weather Forecast of the Argentine Meteorological Service. By Guillermo Hoxmark. June 20, 1925. 23 pp., 5 text figs. (Publ. 2827.)

In press at close of year

VOLUME 77

No. 4. An Introduction to the Morphology and Classification of the Foraminifera. By Joseph A. Cushman. July 21, 1925. 77 pp., 16 pls., 11 text figs. (Publ. 2824.)

SMITHSONIAN ANNUAL REPORTS

Report for 1922.—The complete volume of the Annual Report of the Board of Regents for 1922 was received from the Public Printer in October, 1924.

Annual Report of the Board of Regents of the Smithsonian Institution, showing operations, expenditures, and condition of the Institution for the year ending June 30, 1922. xii+554 pp., 142 pls., 49 text figures. (Publ. 2724.)

The appendix contained the following papers:

Who will promote science? by C. G. Abbot.

Recent discoveries and theories relating to the structure of matter, by Karl Taylor Compton.

The architecture of atoms and a universe built of atoms, by C. G. Abbot.
Aeronautic research, by Joseph S. Ames.
Photosynthesis and the possible use of solar energy, by H. A. Spoehr.
Fogs and clouds, by W. J. Humphreys.
Some aspects of the use of the annual rings of trees in climatic study, by Prof. A. E. Douglass.
The age of the earth, by T. C. Chamberlin and others.
How deep is the ocean? by C. G. Abbot.
Two decades of genetic progress, by E. M. East.
Observations on a Montana beaver canal, by S. Stillman Berry.
The Republic of Salvador, by Paul C. Standley.
The tent caterpillar, by R. E. Snodgrass.
The life history and habits of the solitary wasp, *Philanthus gibbosus*, by Edward G. Reinhard.
The use of idols in Hopi worship, by J. Walter Fewkes.
Two Chaco Canyon pit houses, by Neil M. Judd.
Collections of Old World archeology in the United States National Museum, by I. M. Casanowicz.
The "Shake Religion" of Puget Sound, by T. T. Waterman.
Excavations at Askalon, by Prof. J. Garstang.
National efforts at home making, by F. H. Newell.
Ideals of the telephone service, by John J. Carty.

Report for 1923.—The complete volume of the Report of the Board of Regents for 1923 was received from the Public Printer in June, 1925.

Annual Report of the Board of Regents of the Smithsonian Institution, showing operations, expenditures, and condition of the Institution for the year ending June 30, 1923. xii+578 pp., 100 pls., 72 text figures. (Publ. 2758.)

The appendix contained the following papers:

The constitution and evolution of the stars, by Henry Norris Russell.
The sun and sunspots, 1820–1920, by E. Walter Maunder.
Joining the electric wave and heat wave spectra, by E. F. Nichols and J. D. Tear.
The possibilities of instrumental development, by George E. Hale.
The borderland of astronomy and geology, by Prof. A. S. Eddington.
Atmospheric nitrogen fixation, by Eric A. Lof.
The place of proteins in the diet in the light of the newer knowledge of nutrition, by H. H. Mitchell.
The story of the production and uses of ductile tantalum, by Clarence W. Balke.
The composition of the earth's interior, by L. H. Adams and N. L. Williamson.
Diamond-bearing peridotite in Pike County, Ark., by H. D. Miser and C. S Ross.
Recent progress and trends in vertebrate paleontology, by W. D. Matthew.
Animals in the National Zoological Park, by N. Hollister.
The burrowing rodents of California as agents in soil formation, by Joseph Grinnell.
The natural history of China, by A. de C. Sowerby.
Life in the ocean, by Austin H. Clark.

A study of the flight of sea gulls, by R. C. Miller.
Insect musicians and their instruments, by R. E. Snodgrass.
The gardens of ancient Mexico, by Mrs. Zelia Nuttall.
The Hovenweep National Monument, by J. Walter Fewkes.
The origin and antiquity of the American Indian, by A. Hrdlička.
Ruined cities of Palestine, east and west of the Jordan, by Arthur W. Sutton.
The anthropological work of Prince Albert 1st of Monaco and recent progress in human paleontology in France, by Marcellin Boule.
The utilization of volcanic steam in Italy.
Proposed tidal hydroelectric power development of the Petitcodiac and Memramcook Rivers, by W. Rupert Turnbull.
Sir James Dewar, by Sir James Crichton-Browne.
J. C. Kapteyn, by A. Van Maanen.
Julius Von Hann, by C. G. Simpson.

Report for 1924.—The report of the executive committee and proceedings of the Board of Regents of the Institution, and the report of the secretary, both forming parts of the annual report of the Board of Regents to Congress, were issued in pamphlet form in December, 1924.

Report of the executive committee and proceedings of the Board of Regents of The Smithsonian Institution for the year ending June 30, 1924. 14 pp. (Publ. 2792.)
Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1924. 124 pp. (Publ. 2791.)

The general appendix to this report, which was in press at the close of the year, contains the following papers:

The origin of the solar system, by J. H. Jeans.
The electrical structure of matter, by Prof. Sir Ernest Rutherford.
The physicist's present conception of an atom, by R. S. Millikan.
The vacuum—there's something in it, by W. R. Whitney.
The use of radium in medicine, by Antoine Béclère.
Clear fused quartz made in the electric furnace, by Edward R. Berry.
The drifting of the continents, by Pierre Termier.
The probable solution of the climatic problem in geology, by William Ramsay.
A modern managerie; more about the National Zoological Park, by N. Hollister.
Nests and nesting habits of the American eagle, by Francis H. Herrick.
The breeding places of the eel, by Johs. Schmidt.
Cankerworms, by R. E. Snodgrass.
A botanical trip to Ecuador, Peru, and Bolivia, by A. S. Hitchcock.
Orchid collecting in Central America, by Paul C. Standley.
Sketches from the notebook of a naturalist-traveler in Oceania during the year 1923, by Casey A. Wood.
Historical tradition and oriental research, by James Henry Breasted.
Shamanism of the natives of Siberia, by I. M. Casanowicz.
Egypt as a field for anthropological research, by Prof. P. E. Newberry.
North American Indian dwellings, by T. T. Waterman.
The nature of language, by R. L. Jones.
John Mix Stanley, artist-explorer, By David I. Bushnell.
Herluf Winge, by Th. Mortensen.

SPECIAL PUBLICATIONS

Smithsonian Mathematical Tables—Hyperbolic Functions, Third reprint. Prepared by George F. Becker and C. E. Van Orstrand. December 10, 1924. 321 pp. (Publ. 1871.)

The Relations of the Smithsonian Institution to the National Government. February 5, 1925. 8 pp.

Niagara Falls: Its Power Possibilities and Preservation. By Samuel S. Wyer. January 15, 1925. 28 pp., 2 pls., 4 figs. (Publ. 2820.)

Title page and index of Volume 67, Smithsonian Miscellaneous Collections. (Publ. 2790.)

Title page and contents of Volume 74, Smithsonian Miscellaneous Collections. (Publ. 2821.)

Title page and contents of Volume 76, Smithsonian Miscellaneous Collections. (Publ. 2822.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The publications of the National Museum are: (*a*) The annual report, (*b*) the Proceedings of the United States National Museum, and (*c*) the Bulletin of the United States National Museum, which includes the contributions from the United States National Herbarium. The editorship of these publications is vested in Dr. Marcus Benjamin.

During the year ending June 30, 1925, the Museum published 1 annual report, 2 volumes of proceedings, 2 complete bulletins, 1 part of a bulletin, 3 parts of 2 volumes in the series Contributions from the United States National Herbarium, and 66 separates from the proceedings.

The issues of the bulletins were as follows:

Bulletin 100. Contributions to the Biology of the Philippine Archipelago and Adjacent Regions. Volume 6, part 1. Marine Diatoms of the Philippine Islands. By Albert Mann.

Bulletin 129. The Spider Crabs of America. By Mary J. Rathbun.

Bulletin 130. Life Histories of North American Wild Fowl. Order Anseres (Part). By Arthur Cleveland Bent.

Of the separate papers of the Contributions from the United States National Herbarium the following were issued:

Volume 20, part 13. Revision of the American Species of Rinorea. New Plants from Venezuela. Hemibaccharis. A new Genus of Baccharidinae. By S. F. Blake.

Volume 20, part 14. The American Species of Canavalia and Wenderothia. By C. V. Piper.

Volume 23, part 4. Trees and Shrubs of Mexico. (Passifloraceae-Scrophulariaceae.) By Paul C. Standley.

Of the separates from the proceedings, 4 were from volume 64, 15 from volume 65, 31 from volume 66, and 16 from volume 67.

PUBLICATIONS OF THE NATIONAL GALLERY OF ART

The National Gallery of Art issued during the year the following publications:

Catalogue of a collection of water-color paintings of the Grand Canyon of the Colorado, Yellowstone National Park, Yosemite Valley, Zion National Park, Utah National Park, and the Monterey Coast of California, by Mr. Gunnar Widforss. On view in the National Gallery, December, 1924, to January, 1925. 4 pp.

Catalogue of a collection of busts of prominent personages in bronze and terra cotta, by Mrs. Nancy Cox-McCormack. On view in the National Gallery, December 16, 1924, to January 16, 1925. 4 pp.

Catalogue of a collection of portraits and studies in different techniques, by Leo Katz, of Vienna, Austria. On view in the National Gallery, January 16 to February 15, 1925. 4 pp.

Catalogue of recent miniature portraits by Alyn Williams, P. R. M. S. (president Royal Miniature Society), and portrait busts in bronze and plaster, relief portraits, medallions, carvings in precious and semiprecious stones, and some great seals, by Cecil Thomas, R. M. S. On view in the National Gallery, March 3 to March 22, 1925. 8 pp.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau of American Ethnology is under the direction of Mr. Stanley Searles, editor. During the year, there were published two annual reports and one bulletin as follows:

Thirty-eighth Annual Report. Accompanying paper: An Introductory Study of the Arts, Crafts, and Customs of the Guiana Indians (Roth). vii, 743 pp., 183 pls., 341 figs.

Thirty-ninth Annual Report. Accompanying paper: The Osage Tribe: The Rite of Vigil (La Flesche). 636 pp., 17 pls., 4 figs. (Received July 13, 1925.)

Bulletin 78. Handbook of the Indians of California (Kroeber). xviii, 995 pp., 83 pls., 78 figs. (Received July 17, 1925.)

At the close of the year there were in press or in preparation three annual reports as follows:

Fortieth Annual Report. Accompanying papers: The Mythical Origin of the White Buffalo Dance of the Fox Indians; The Autobiography of a Fox Indian Woman; Notes on Fox Mortuary Customs and Beliefs; Notes on the Fox Society Known as "Those Who Worship the Little Spotted Buffalo"; The Traditional Origin of the Fox Society Known as "The Singing Around Rite." (Michelson.)

Forty-first Annual Report. Accompanying paper: Salish Basketry (Boas).

Forty-second Annual Report. Accompanying paper: Social Organization and Social Usages of the Indians of the Creek Confederacy; Religious beliefs and medical practices of the Creek Indians (Swanton).

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the association to the Secretary of the Smithsonian

Institution and are communicated by him to Congress as provided by the act of incorporation of the association.

Volume II, Parts I and II, of the annual report for 1919 and the supplemental volume to the report for 1921, entitled "Writings in American History," were issued during the year. The annual reports for 1920, 1921, and 1922, and the supplemental volume to the report for 1922 were in press at the close of the year.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Twenty-seventh Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with the law, on December 8, 1924.

SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION

The editor has continued to serve as secretary of the Smithsonian advisory committee on printing and publication, to which are referred for consideration and recommendation all manuscripts offered to the Institution and its branches. Five meetings were held during the year and 75 manuscripts acted upon.

Respectfully submitted.

W. P. True, *Editor.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDED JUNE 30, 1925

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the Institution and a statement of the appropriations by Congress for the following Government bureaus in the administrative charge of the Smithsonian Institution: The National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, the International Catalogue of Scientific Literature, and the National Gallery of Art, for the fiscal year ended June 30, 1925.

SMITHSONIAN INSTITUTION

Condition of the endowment fund July 1, 1925

The sum of $1,000,000, deposited in the Treasury of the United States under act of Congress, is part of a permanent endowment fund which includes the original Smithson fund and additions accumulated by the deposit of savings and bequests from time to time. Subsequent bequests and gifts and the income therefrom, when so required, are invested in approved securities. The several specific funds so invested are now constituted and classed as follows:

Consolidated fund

Avery fund	$32,669.55
Virginia Purdy Bacon fund	62,272.93
Lucy H. Baird fund	1,528.09
Chamberlain fund	35,000.00
Hamilton fund	500.00
Caroline Henry fund	1,223.33
Hodgkins general fund	37,275.00
Bruce Hughes fund	13,839.90
Morris Loeb fund	5,814.00
Lucy T. and George W. Poore fund	14,183.14
Addison T. Reid fund	6,639.16
Rhees fund	357.34
George H. Sanford fund	615.32
Smithson fund	1,468.74
Total consolidated fund	213,386.50
Charles D. and Mary Vaux Walcott research fund	11,520.00

The total amount of dividends and interest received by the Institution from the Freer estate during the year for all purposes was $231,073.64.

The itemized report of the auditor, The Capital Audit Co., certified public accountants, is filed in the office of the secretary.

DETAILED SURVEY OF FINANCIAL OPERATIONS

Parent fund

Balance on hand or in time deposits, July 1, 1924		$4,476.59
Receipts:		
Income, consisting of interest and receipts from miscellaneous sources available for general purposes	$57,606.84	
International exchanges, repayments to the Institution	4,900.22	
Total receipts		62,507.06
Total resources for general purposes		66,983.65
General expenditures:		
Care and repair of buildings	$7,576.16	
Furniture and fixtures	981.16	
General administration	24,337.63	
Library	3,133.47	
Publications (comprising preparation, printing, and distribution)	15,003.68	
Researches and explorations	4,774.77	
International exchanges	4,114.33	
Total general expenditures		59,921.20
Balance June 30, 1925		7,062.45

Funds for specific objects, including payment and return of funds advanced for field expenses and other temporary transactions during the year

Balance on hand or in time deposits July 1, 1924		$66,854.84
Receipts:		
Avery fund	$3,416.42	
Virginia Purdy Bacon fund	12,009.52	
Lucy H. Baird fund	118.20	
Frances Lea Chamberlain fund	2,758.00	
Fred. G. Cottrell fund	3,750.00	
Endowment fund (general)	210.00	
Endowment campaign expense fund	2,000.00	
Far East expedition fund	2,000.00	
David C. Graham fund	200.00	
Dr. W. L. Abbott Haitian botanical expedition	500.00	
Hamilton fund	189.40	
Harriman trust fund	12,546.25	
Caroline Henry fund	96.13	
Hodgkins fund, specific	7,015.40	
Bruce Hughes fund	1,087.44	
Morris Loeb fund	3,065.79	
National Gallery of Art building plans fund	264.55	

Receipts—Continued.		
North American Wild Flowers publication fund	$45,576.84	
Lucy T. and George W. Poore fund	2,967.08	
Addison T. Reid fund	1,183.23	
Researches in paleontology	1,409.09	
Rhees fund	62.98	
John A. Roebling funds	28,278.15	
George H. Sanford fund	114.46	
Smithsonian scientific series fund	8,250.00	
Swales fund	300.00	
Charles D. and Mary Vaux Walcott fund	720.00	
Refund of temporary advances	8,163.95	
Total receipts		$148,252.88
Total resources		215,107.72
Expenditures:		
Avery fund, invested	$3,112.03	
Virginia Purdy Bacon fund, invested and expended	12,410.59	
Lucy H. Baird fund, invested	178.51	
Chamberlain fund, for specimens, etc	2,043.24	
Far East expedition fund, expended	2,693.62	
Harriman trust fund, for researches and specimens	12,026.09	
Caroline Henry fund, invested	149.33	
Hodgkins fund, for researches	6,309.32	
Bruce Hughes fund, invested	1,826.28	
Morris Loeb fund, expended	3,583.68	
National Gallery of Art building plans fund	10,005.00	
North American Wild Flowers publication fund, expended	33,194.84	
Lucy T. and George W. Poore fund, invested and expended	999.55	
Addison T. Reid fund, invested	1,746.16	
Researches in paleontology, expended	1,179.48	
Research Corporation, rocket investigation	750.00	
Rhees fund, invested	89.34	
John A. Roebling funds, solar research, etc., expended	27,400.21	
W. A. Roebling mineral fund, expended	373.03	
George H. Sanford fund, invested	109.32	
Swales fund, for specimens	356.32	
Charles D. and Mary Vaux Walcott fund, expended	896.24	
Temporary advances for field expenses, etc	6,902.35	
Total expenditures		128,334.53
Balance June 30, 1925		86,773.19

Charles L. Freer bequest

Balance on hand or in time deposits, July 1, 1924	$31,233.73	
Receipts:		
Dividends, interest, and miscellaneous receipts	231,073.64	
Total resources		262,307.37

Expenditures:		
Operating expenses of the gallery, salaries, purchase of art objects, field expenses, and incidentals	$99,744.53	
Investments in sinking fund, including interest	84,445.73	
Total expenditures		$184,190.26
Balance June 30, 1925		78,117.11

SUMMARY

Total balances of all funds, July 1, 1924	102,565.16
Receipts during year ending June 30, 1925:	
Parent fund for general expenses	62,507.06
Revenue and principal of funds for specific objects, except Freer bequest	148,252.88
Freer bequest	231,073.64
Total	544,398.74
Expenditures:	
General expenses of the Institution	59,921.20
Specific objects, except Freer bequest	128,334.53
Freer bequest	184,190.26
Total balances of all funds June 30, 1925	171,952.75
Total	544,398.74

All payments are made by check, signed by the Secretary of the Institution, on the Treasurer of the United States, and all revenues are deposited to the credit of the same account. In some instances deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The practice of investing temporarily idle funds in time deposits has proven satisfactory. During the year the interest derived from this source, together with other similar items, has resulted in a total of $1,610.15.

The following appropriations for the Government bureaus under the administrative charge of the Smithsonian Institution were made by Congress for the fiscal year 1925:

Bureau:	Appropriation
International Exchanges	$49,550.00
American Ethnology	57,160.00
International Catalogue of Scientific Literature	8,861.66
Astrophysical Observatory	21,580.00
Additional Assistant Secretary	6,000.00
Additional fire protection	8,500.00

Bureau—Continued.		
National Museum—		Appropriation
Furniture and fixtures	$21,800.00	
Heating and lighting	77,560.00	
Preservation of collections	434,482.00	
Building repairs	11,000.00	
Books	2,000.00	
Postage	450.00	
		$547,292.00
National Gallery of Art		20,158.00
National Zoological Park		151,487.00
Printing and binding		90,000.00
Total		960,588.66

Respectfully submitted.

HENRY WHITE,
FREDERIC A. DELANO,
R. WALTON MOORE,
Executive Committee.

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDED JUNE 30, 1925

ANNUAL MEETING DECEMBER 11, 1924

Present: The Hon. William H. Taft, Chief Justice of the United States, chancellor; Senator Reed Smoot; Senator George Wharton Pepper; Representative Albert Johnson; Representative R. Walton Moore; the Hon. George Gray; the Hon. Henry White; Mr. Charles F. Choate, jr.; Mr. Robert S. Brookings; Mr. Frederic A. Delano; and the secretary, Dr. Charles D. Walcott.

DEATH OF SENATOR LODGE

The secretary announced the death, on November 9, 1924, of Senator Henry Cabot Lodge, who was first appointed a Regent on January 6, 1890, as a Member of the House of Representatives, serving until January 25, 1893; and again as a Member of the Senate, on December 7, 1905, serving continuously until his death, aggregating a total of 22 years as a member of the board.

The following resolutions were then adopted:

Whereas, the Board of Regents of the Smithsonian Institution, having learned with profound sorrow of the death, on November 9, 1924, of Henry Cabot Lodge, United States Senator from Massachusetts and a Regent of the Institution for 22 years: Be it

Resolved, That the board desire to record here their sense of the irreparable loss sustained by the Institution in the passing away of their distinguished colleague, whose keen, constructive interest in the affairs of the Institution led him to place his broad knowledge and large experience at its service at all times. Senator Lodge's fame as a scholar, citizen, and statesman is too well known to require mention here. He was an outstanding figure in the Nation, and his death is deeply deplored.

Resolved, That these resolutions be spread upon the records of the board and that a copy thereof be transmitted to our late associate's family.

APPOINTMENT OF REGENTS

The secretary announced that under date of December 2, the President pro tempore of the Senate had appointed Senator Reed Smoot as a Regent to succeed Senator Lodge, deceased.

Also that he had received the resignation of Senator McCormick as a Regent, which he had transmitted to the President pro tempore of the Senate who had appointed Senator George Wharton Pepper to fill the vacancy on December 8.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE

The board adopted a resolution providing for the expenditure in the usual manner of the income of the Institution during the fiscal year ending June 30, 1926.

NATIONAL MUSEUM OF ENGINEERING AND INDUSTRY

The secretary brought before the board a petition from the National Museum of Engineering and Industry, urging the setting aside of a specified plot of ground south of the Smithsonian Building on which to erect a museum building; adding that the matter had received the attention of the executive committee.

A full discussion upon the various phases of the proposed project ensued, after which the board adopted resolutions expressing its sympathy with the proposal and its willingness to take definite steps when sufficient funds to cover the initial cost involved had been deposited with the Smithsonian Institution by the National Museum of Engineering and Industry.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

The secretary submitted in printed form the annual report of the executive committee, showing the financial condition of the Institution at the close of the fiscal year ending June 30, 1924.

ANNUAL REPORT OF THE PERMANENT COMMITTEE

Solar radiation researches.—This work has been conducted for several years by Assistant Secretary Abbot at stations on Montezuma Mountain, Chile, and on Mount Harqua Hala, Ariz. The operations are financed by an annual grant of $5,000 from the Hodgkins fund of the Smithsonian Institution and through the generosity of a public-spirited citizen, Mr. John A. Roebling.

Freer sinking fund.—The permanent committee's last report mentions the establishment of a sinking fund for the purpose of safeguarding the principal and income of the Freer Foundation for Oriental Art. Under it the income of the Freer bequest in excess of 6 per cent on the value of the foundation at the time of Mr. Freer's death is to be reinvested in high-class securities and real-estate mortgages until an amount equal to the original foundation is reached. The amount thus invested to date is $153,463.75.

Consolidated fund.—Under the organic act the sum authorized to be deposited in the United States Treasury at 6 per cent interest as the "Smithson fund" is limited to $1,000,000. This limit was reached in 1917, and bequests, gifts, and interest earnings in excess of this amount have been constituted a consolidated fund, which is invested in securities approved by your permanent committee. This fund now totals $213,386.50.

ANNUAL REPORT OF THE NATIONAL GALLERY OF ART COMMISSION

The fourth annual meeting of the National Gallery of Art Commission was held December 9, 1924.

The annual report of the secretary of the commission for 1924 calls attention to the installation during the year of a collection of World War portraits in

the Natural History Building. A list recently made of the portraits in oil and pastel now in possession of the Institution and in part available for assemblage in the portrait gallery, numbers upward of 400.

The desirability of improving the standard of the portraits of personages of national distinction, which in time might be included in the National Portrait Gallery, was considered, but no definite action was taken.

The preliminary plans for the proposed National Gallery Building as prepared by Mr. Platt, the architect, were considered.

The very important problem of the inclusion in the building of collections both of art and history received attention, and the view prevailed that it would be advantageous, at least for a time, to have the two in the same building but distinctly separated.

The chairman submitted the resignation of Mr. Edwin H. Blashfield, and it was voted to recommend Mr. E. C. Tarbell to the Board of Regents as his successor.

The secretary of the commission announced the expiration of the three-year terms of the following members of the commission: Messrs. John E. Lodge, James Parmelee, and E. W. Redfield, and their election for four years was recommended by the commission.

Then followed the reelection of the present officers of the commission and also of the members of the executive and advisory committees for the ensuing year.

On motion, the board accepted the report and adopted the following resolution:

Resolved, That the Board of Regents of the Smithsonian Institution hereby accepts with regret the resignation of Mr. E. H. Blashfield as a member of the National Gallery of Art Commission; elects Mr. Edmund C. Tarbell for the remainder of Mr. Blashfield's term, namely, to December 14, 1927; reelects Messrs. John E. Lodge, James Parmelee, E. W. Redfield, and Mr. Daniel Chester French as members for the full term of four years.

ANNUAL REPORT OF THE SECRETARY

In submitting his annual report of the operations of the Institution for the fiscal year ending June 30, 1924, the secretary said that since the last annual meeting of the Regents on December 13, 1923, a total of 110 publications have been issued by the Institution and the Government branches in its administrative charge. Of this number 40 were issued by the Institution, 67 by the National Museum, and 3 by the Bureau of American Ethnology. It is by means of these various series of publications, together with exhibits, lectures, radio talks, and correspondence, that the Institution carries out one of its primary objects, the "diffusion of knowledge among men." The publications are distributed free to libraries, scientific and educational institutions, and interested individuals throughout the world.

The Smithsonian Annual Report continues to attract widespread popular interest. These reports have been issued two years late since the World War, but Congress has provided an additional amount to enable the Institution to bring out two in one year, and at the present time the report for 1923 is ready for paging and all the galleys of the report for 1924 have been received from the printer.

ADJOURNED MEETING, JANUARY 5, 1925

Present: The Hon. William H. Taft, Chief Justice of the United States, chancellor; Senator Reed Smoot; Senator A. Owsley Stanley; Representative Albert Johnson; Representative R. Walton Moore; Representative Walter H. Newton; Mr. Robert S. Brookings; Mr. Frederic A. Delano; and the secretary, Dr. Charles D. Walcott.

ACKNOWLEDGMENT

The secretary read a letter from Mr. John E. Lodge expressing the grateful acknowledgment of his family for the resolutions adopted by the Board of Regents on December 11, 1924, on the death of his father, Senator Henry Cabot Lodge, a Regent of the Institution.

INCREASE OF ENDOWMENT

The executive committee reported that it had carefully considered a plan submitted by a New York firm for increasing the endowment of the Institution, and had received the opinion of the Attorney General that there was no legal impediment in the way of engaging the firm for this purpose.

The board adopted a resolution giving the permanent committee power to act in the matter.

REPORT OF SPECIAL COMMITTEE ON PLANS FOR NEW BUILDING FOR NATIONAL GALLERY OF ART

Mr. Delano read the following report:

To the Board of Regents.

GENTLEMEN: Your committee appointed by the board on February 14, 1924, for the purpose of collaborating with the architect in the preparation of plans for the proposed National Gallery of Art Building, met at the Smithsonian Institution on October 28, 1924.

Mr. Charles A. Platt, the architect, who had recently returned from a tour of the art galleries abroad, submitted preliminary sketch plans for the building. These comprised plans of the three floors with sections, and a detailed drawing of the south front. Plans of a number of European galleries, drawn to the same scale, were presented for comparison, and details of lighting adaptation to spaces and various other requirements of the structure were considered. Mr. Platt explained that it was expected that granite would be employed in the construction, and that the building, which will be 320 by 570 feet, would contain possibly 10,000,000 cubic feet. He said also that if required the plans could be ready for the beginning of the work within six months.

The provisional plans as presented were approved by the committee as a basis for future study.

Respectfully submitted.

HENRY WHITE, *Chairman,*
FREDERIC A. DELANO,
HERBERT ADAMS,
GARI MELCHERS,
J. H. GEST,
CHARLES D. WALCOTT (ex officio),
Special Committee.

REMISSION OF FREER INCOME TAX

The secretary called attention to the passage by the Senate of H. R. No. 8100 for the relief of Mr. Freer's estate, by which taxes to the amount of $74,889.56 have been remitted by the Government.

OPENING OF MUSEUM BUILDINGS ON SUNDAYS

The secretary brought up the question of the opening of all of the Museum buildings on Sundays, stating that it was now impossible to do so owing to the few watchmen allowed by the appropriations. The Natural History (or new) Building was open from 1.30 to 4.30, but the other buildings were closed. He thought that if five more watchmen were provided all the buildings could be open on Sunday, at least for the afternoon.

In this connection he also spoke of the few visitors on Christmas and New Year's Days, and proposed the closing of the buildings on those days, so as to give the watchmen an opportunity for rest which was now denied them.

After discussion, resolutions were adopted covering these matters.

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GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1925

ADVERTISEMENT

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1925.

SPIRAL NEBULÆ AND THE STRUCTURE OF SPACE[1]

By C. Wirtz

University Observatory, Kiel

1. The inquiry into the structure of space lies within the province of astronomy. For this purpose observation will give us the position of numerous physical points which must serve as the skeleton upon which we model our conception. Observation gives us knowledge of the motions of the heavenly bodies. The orbits derived from these motions should serve as the basis for some conclusions as to the character of the space in which these bodies are imbedded. Several decades ago the distances measured by astronomy out into the world of the stars were too small to be expected to show any divergencies of structure from ordinary Euclidean conceptions. Within the relatively small solar system all motions take place so accurately in accordance with the laws of Newton and Euclidean geometry that no modifications are necessary.

This is remarkable and comforting. In the solar system the apparent movements are rapid and great with reference to the lapse of time during which we may make measures. Accordingly, the numerous complexities of the motions have been recognized and explained. On the other hand with the stars the changes of position are so slow that observations for 2,000 years show no divergences of their paths from straight, uniform motion. The stars of the heavens behave to us as would our planetary system to an observer living only a few seconds; that is, for such an observer the planets would show no deviation from a uniform rectilinear motion. Yet we must not push the analogy further for he could from such observations correctly construct the plan of the solar system.

In every way we become convinced that the dimensions of our solar system with its known structure and rapid motions are too restricted to help us in our problem of the structure of space. In-

[1] Reprinted (by special permission of the director of Scientia) from the issue of November, 1925, of Scientia. International Review of scientific synthesis, edited by Eugenio Rignano, published by eight publishers: Williams & Wilkins Co., Baltimore; Williams & Norgate, London; Felix Alcan, Paris; Nicola Zanichelli, Bologna; Akad, Verlagsgesellschaft m. b. H., Leipzig; Ruiz Hermanos, Madrid; Renascenca Portiguesa, Porto; The Maruzen Co., Tokyo.

stinctively we turn to those objects to which we ascribe the greatest distances from us. We hope that in the light coming to us from these distant objects we may find something serving as testimony of the long path it has traversed through this space. Speaking metaphorically, from the dust of the journey we would infer something of the nature and direction of the path as well as the region through which the journey lay.

2. Which, then, are the most distant bodies? Through a process of elimination we are quickly left with only two possible kinds of bodies which mostly or wholly lie without that part of space which is filled with stars in varying number. Our sun is somewhat near the center of this universe of stars. The boundary of it we may practically place where the star density is one one-hundreth that close to our sun. To realize the vanishingly small density in which the matter, collected in the form of stars exists, we may think of them as grains of sand so scattered that each grain is distant about 100 kilometers (62 miles) from its nearest neighbor. This shows to scale the relative emptiness of space. The limit of our universe of stars as above defined lies so far away (30,000 light-years) that it takes 30,000 years for light to come from the boundary to us. Beyond, outside the bounds of our stellar system (galaxy) lie numerous globular star clusters and spiral nebulæ—not all the clusters but all of the nebulæ.

How may we obtain an idea or measure of these immensely great distances? Direct trigonometric triangulation naturally can give us no information since we have to do with annual parallaxes giving angles as small as 0.000005 angular seconds, and indeed less. The motions of the spiral nebulæ give us the answer and a riddle at the same time. For 15 years we have known that the lines in the spectra of the spiral nebulæ show shifts which have been interpreted as Doppler displacements, a physical interpretation which is taken to indicate and measure radial velocities of the nebulæ. These velocities are much greater than those generally found for the fixed stars. They may be of the order of 2,000 kilometers (1,250 miles) per second. At present radial velocities have been determined for some 50 spiral nebulæ. These have already been analyzed to discover interesting systematic characteristics in the nebular movements.

All apparent motions of the heavenly bodies are made up of two components: Their own or "peculiar motion" and a mirroring in them of the motion of the observer.[2] The latter varies for different directions relative to our movement and with the distance of the

[2] NOTE BY THE TRANSLATOR.—An analogous motion may be observed from the window of a rapidly moving train. The trees of the middle distance seem to recede, while the more distant ones move along with the train.

body from the observer. It is possible by combination in a mathematical discussion of all the motions of the various bodies to find the motion of the observer relative to the "centroid" (center of mean positions) of the moving bodies. When we seek this datum from the motions of the spiral nebulæ we reach an unexpected result. The "apex," or goal of the motion of the sun, has no apparent relationship with that found from a similar discussion of the motions of the stars. This apex, determined from the nebular motions, lies not far from the pole of the earth's orbit. There is a further and not less unexpected result. The velocity of the sun relative to the centroid of the spiral nebulæ is no longer the commonly found value from various discussions of stellar motions, 20 kilometers (12 miles) per second, but about 700 kilometers (435 miles) per second. It can not be the sun alone which is thus moving relatively to the spiral nebulæ. For such a great velocity would have its image in the surrounding stars (parallactic motion); such is not present.

3. We are therefore forced to the conclusion that our whole galaxy of stars, the milky way family as a body, is moving with this great velocity relative to the centroid of the spiral nebulæ. A further conclusion results: The milky way system and the spiral nebulæ must be considered as related systems—that is, the spiral nebulæ are distant galaxies and our galaxy or milky-way system, viewed from the spiral nebulæ, would have the appearance of a cosmical nebula.

There is another surprise. If we eliminate the known motion of the sun from the observed motion of the spiral nebulæ we would expect to find, according to the underlying assumptions of the procedure, that in the mean they would be zero. But that is not at all the case. We find that the system of spiral nebulæ tends to scatter outwards into space. Literally stated, the spirals are moving outwards from the present position of the observer with a velocity of about 800 kilometers (497 miles) per second.

We can obtain another measure of the distance of these nebulæ, although of small accuracy. The goal of the solar motion may be found not only from a discussion of the movements of the nebulæ in a radial direction but also from their movements at right angles to this, their angular displacements. The natural lack of sharpness in the outlines of these hazy objects militates against the accuracy of position determinations, so that the proper motions of any individual nebula can not be indicated with any accuracy. But that does not exclude the determination of a statistical mean indicating the part of movement of all of them, which is produced by the motion of the observer himself. If we combine this uncertain but at any rate too great value of the angular motion with the surer value of the

radial motion, there can be obtained a lower limit for the distance of the spiral nebulæ. There results a value of 80,000 light-years.

If we are convinced that the spirals are distant milky-way systems, there is available yet another method which allows us to push yet further the lower limit of their distance. New stars (novæ) appear from time to time in certain spiral nebulæ. We can compare these with those which appear in our own milky way. Let us assume that their greatest brightness is the same no matter in which system they occur. This leads to an estimate of 600,000 light-years for the nearest spiral nebulæ. This further signifies that their linear dimensions are of the same order as those of our own galaxy.

4. Now, convinced that the light from the spirals must travel this immensely long journey through space to reach us, let us recall our earlier query: Does this light bring us in its aspects any trace of the structure of this space which does not correspond to the structure of infinite Euclidean space?

Perhaps. First let us consider the apparent dispersion outwards, relative to our position of observation, of the matter concentrated in these nebulæ. In this in itself remarkable phenomenon we will find something further to strike us. We will probably not be greatly wrong if, as a first approximation, we ascribe the same linear dimensions to all of the spiral nebulæ. Then in their apparent angular extent we have a measure of their individual distances. Using this assumption as the basis of our inquiry we reach a startling result: With increasing distance of the nebulæ the observed outwardly directed velocity increases, and it increases at a rapid rate, such that when the distance increases tenfold the radial velocity increases about 1,200 kilometers (745 miles) per second. This must mean that the farther away the object is in the depths of Euclidean space the more rapid is the dispersion of its matter into that space.

Is this interpretation of the observed facts, which assumes infinite space, necessary? Naturally not. There are no absolutely necessary descriptions of observed facts. We should try to formulate that description which is the most satisfying in the sense that it explains a greater number of isolated phenomena than the older conception.

5. There is a structure of space in which the phenomena which we have observed in the spiral nebulæ will be accurately reproduced. This structure occurs in the cosmology of the Dutch astronomer, W. de Sitter. The world of de Sitter is a four-dimensional continuum of space and time, forming the surface of a sphere in five dimensional coordinates. This sounds richly complex, indeed incomprehensible. It is not possible to represent it graphically. But representation is a product of our imagination, knowledge of our

reason. The understanding can well conceive what our imagination can not picture. That is the case here. Man, bodily constructed in three dimensions, can not picture things in four or more dimensions. Nevertheless, the following conceit may help us better to understand the space of de Sitter.

If we eliminate two dimensions of a four-dimensional space, the latter reduces to a surface. But what is the character of this surface?

We can take in at a glance the phenomena which could be understood by a being of two dimensions living on the surface of a sphere. From these phenomena he could infer the mathematical characteristics of his cosmical space. This being would recognize the extended but not infinite character of his sphere of existence. Further, he would recognize something which is really the radius of the three-dimensional sphere upon whose surface he is constrained to exist and which might become an object for research. It is the radius of curvature of his world space. He can talk of it, he can determine a linear measure of it. A spatial representation in three dimensions will never be possible to him who can know only two dimensions. The two-dimensional observer, carrying out certain direct measures upon this surface-of-a-sphere limited universe, will find that the value of his determinations of the number π will not be constant. It will be found that it is dependent upon the greatness of the circle, that it is always less than 3.14159, and that the value of π which he finally decides upon will be the maximum limit toward which all his values tend to approach.

The strange cosmos of de Sitter, reduced to two dimensions, does not become such a simple surface-of-a-sphere world but one lying on a hyperbola of revolution. Our physicist, confined upon the surface of this hyperboloid, can make certain observations comparable to those of our real world. For instance, he will find that the number of Archimedes is always less than our value of π. It may be mentioned as remarkable that all the phenomena of probability from which we may determine a value of π will lead to a value which is greater than the value found from Euclidean geometry. Taken by itself this is possibly only a curiosity and might signify little. Nevertheless certain modern astronomical phenomena can be given an interpretation which points the same way.

This phenomenon occurs in de Sitter's world, although its existence was not known at the time he constructed his cosmology (1917). With increasing distance from the center of his coordinate system, natural phenomena occur slower and slower, and of course all natural clocks go likewise slower and slower. Especially is this true with atomic vibrations. This decrease in vibration time can be measured for it will be impressed upon the light coming to us. It means that

spectrum lines from distant sources must be shifted toward the red even though the source is at rest. A particle once present in empty space will be driven outward with an acceleration which increases with the distance. In de Sitter's world there are, therefore, two causes for a shift of the spectrum lines toward the red—the general dispersion of matter outwards toward the limits of space and the slowing up of natural time apparent in all distant objects, even though they are at rest, relative to the origin of coordinates.

Because of the symmetry of the formula expressing de Sitter's world, any desired point may be chosen for the zero point of coordinates. That means that there exists no difference in the observed run of phenomena no matter what the point of observation, even though at the boundary of de Sitter's space.

Is it possible to obtain a measure of this slowing up of natural processes at great distance? Yes, and it follows from de Sitter's theory that there is not only the shifting of the spectrum lines to the red but also, as already noted, the increase of this shift with the increasing distance of the object. These facts should occur in the spiral nebulæ as follows: The radial movements outward (Doppler displacement in spectrum) of the spiral nebulæ must tend to greater and greater positive values as the diameters of the nebulæ decrease.

A discussion of the observations gave a verification of the above prediction. The cosmos of de Sitter allows yet other predictions, but we will not discuss them all now. Suffice it to state that we can determine the radius of curvature of the time-space cosmos of de Sitter from phenomena which appear in the spiral nebulæ. The curvature is small, its radius is of the order of 100 millions of light-years. In his continual flow of time an object will never return to the zero point of coordinates. Time is single valued and history will not repeat itself. The cosmology of de Sitter furnishes a sufficient description of the universe.

6. Our preceding discussion is based upon the observation of some 50 nebulæ which are bright enough for the measurement of the line shifts in their spectra. Now there are about 20,000 definitely cataloged nebulæ, and the optical means of our present day should render visible about 3,000,000. What new information may we expect from all of these objects? Just as with the fixed stars, statistical discussions of their distribution, color, photometric measures, etc., will lead to many valuable results.

We will now speak of only one interesting chapter—that relating to the absorption of light in space. It is evidently very important, for in a last analysis this absorption will play a very important

and active part in our world picture. To be more definite, let us suppose this absorption to be of the magnitude produced by that of a thick meteorological fog. Then light coming from beyond a certain distance will be completely extinguished. We could receive no information from more distant bodies. Our universe would have the following appearance: Matter would appear gathered in a spherical star system; our point of outlook would be at its center. It is perhaps disquieting when we remember that already humanity has had to look at the universe in a new way. That was when it threw away the geocentric conception which was a quasi realization of such an absorption cosmos.

Some remarkable results have emerged from measures on the absorption of light in space in which the stars are imbedded. In numerous regions of the sky we see visually and on photographic plates what may be called cosmic clouds. In other places stellar counts reveal the existence of compact impenetrable masses of dust situated at great distances and covering large tracts of the sky. In the color of the stars a selective absorption is apparent, for the more distant stars are redder. This property of absorption shows in a remarkable way—stars in the richer regions are on the whole bluer than where the stars are few. We conclude, *ceteris paribus*, that the regions poor in stars are poor because the more distant stars are hidden behind cloudy veils of small particles which we know selectively transmit red light.

Likewise we encounter in all parts of the milky way traces of both general and selective absorption. However, when we turn to those parts of the sky where we suppose we see great distances out into world space, all traces of both general and selective absorption disappear. This is indicated by the globular star clusters which are placed at some 10,000 to 300,000 light-years away.

7. Can we obtain any evidence of absorption from the spiral nebulæ, the farthest of which may be situated millions of light-years distant? Apparently we can. In them we have surface pictures of great diameter. The surface brightness of these objects can be determined photometrically. This is a very important datum, for the surface brightness should be independent of the distance if space is free of absorption—that is, optically empty. If, instead of taking as our measure of their individually unknown linear distances, we take their apparent diameter, the surface brightness determined for a great number of these bodies should show in a statistical mean no relation to their apparent diameter. We have at our disposal the surface brightness of more than 500 spirals. We find, in submitting all these measures to the precise methods of statistical mathematics,

that there is a slight dependence of the surface brightness upon the apparent diameters in the sense that the surface brightness slightly decreases as the nebula is more distant. For the explanation of this it is natural to have recourse to a general absorption in the space traversed. It may be due to the weakening of the light in passing through an extremely tenuous medium. The selective absorption necessarily bound with the phenomenon has not been demonstrated. If we evaluate the amount of absorption, it is approximately such that when the light passes through a space 3,000 light-years thick the light is weakened 0.00001 magnitude, an amount too small to be effective within our own galaxy.

Bizarre as it may seem, the limit of the system of spiral nebulæ is apparently accessible to our researches, which now extend about to the confines of our stellar galaxy. We may consider that we are approaching this limit if the number of new nebulæ discovered by more and more powerful telescopes grows smaller and smaller, or at any rate does not augment as the optical powers of our instruments increase. We may add that the cumulation of nebular matter toward the north pole of the milky way diminishes as we push farther out into space toward the fainter and fainter nebulæ. Statistics relative to the apparent distribution of the nebulæ lead to this result. Comparison with the relative distribution of the stars, determined by similar means, leads to the conclusion that we should not look to the spiral nebulæ as the birthplace of our stars.

There is a fact which fits with difficulty into the theory which considers the spiral nebulæ as distant milky ways. That is the complete independence of their surface brightness upon their orientation. For, seen from the depths of space, our milky way would appear five times as luminous seen edgewise as broadside on. Further, the surface brightness of the milky way as a whole would be small compared with that of the spiral nebulæ. The milky way system is therefore exceptional, and its brightness places it at the lower rank of its class and as an extreme in any scheme of the evolution of spiral nebulæ. It is not in our power to say whether to place it at the beginning or end of the evolution.

We see that what has been stated relative to several problems which are connected with the spiral nebulæ, or in a more general way with cosmical nebulæ, leads us, literally and metaphorically, to the limits of our knowledge and the confines of space, where reality and fiction, where the physical world and the shadows of our thought confound. Meanwhile neither this world nor science stop there. There is the possibility of finding a response to ques-

tions which agitate human thought and of formulating a sufficient description of the genesis of the universe. It is yet too soon for our perceptions, and their interpretations still contain contradictions. But we may be sure that as long as contradictions exist our intelligences and our imaginations will work for their solution. The contradictions in our conceptions of the universe are the best guarantees for the life of science and the future progress of knowledge.

Only error is life.

—*F. Schiller—Cassandra.*

IMMENSITIES OF TIME AND SPACE[1]

By A. Vibert Douglas, M. B. E., M. Sc.

Within the last twelve months three workers in the realms of mathematical astronomy and cosmogony have brought their researches to conclusions of tremendous importance and widespread interest. So closely are their problems interwoven that it may prove stimulating to consider in some detail the aim of each investigation, the line of argument, and the outstanding results thus far achieved.

STAR'S MASS AND LUMINOSITY

Last year there was given to the Royal Astronomical Society by Prof. A. S. Eddington, F. R. S., a paper which has aroused great interest among astronomers the world over. For many years Professor Eddington has been investigating the radiative properties of a giant star—that is, a star of gigantic size and low density, so low that it could be considered as obeying what in physics are known as the "perfect gas" laws. These investigations led him to the conclusion that the total luminosity of such a star depended chiefly upon its mass and temperature, being almost uninfluenced by other factors. To test the validity of this formula relating luminosity to mass, he first evaluated the constants involved in it from the known values of mass and luminosity of the bright star Capella. He then plotted his relation as shown in the accompanying graph by the curved line. Next he collected all the available data from every possible source, giving both the masses and luminosities of stars and these he plotted individually on his graph. Their close

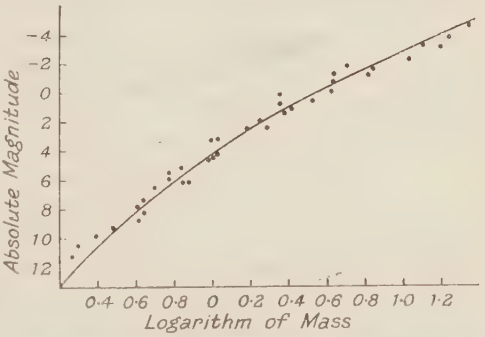

Fig. 1.- Diagram of luminosity—mass relation.

[1] Reprinted by permission from Discovery, Vol. VI, No. 68, August, 1925.

proximity to the theoretical curve is very striking, and forms a strong confirmation of the validity of the theoretical work.

Curiosity, we suppose, led him to wonder where the points would lie representing similar data for the dwarf stars. Now the dwarf stars were so named by Prof. Henry Norris Russell because they are so dense, due to gradual contraction, that it was thought impossible that the gas laws could hold true in their case. Hence a relation between mass and luminosity explicitly based upon strict adherence to the gas laws would not be expected to hold good for a star of the dwarf type. But, *mirabile visu*, the plotted points for data taken from dwarf stars conform as well to the theoretical curve as in the case of the giants.

This was an astounding fact suggesting as it did that the dwarf star, no matter what its density, was in the state of atomic agitation of a perfect gas. The explanation given by Eddington seems plausible, though it has not been accepted unanimously—namely, that where matter is subject to such high temperatures as exist in the stars, temperatures to be measured in millions of degrees, each atom is reduced in effective volume a hundred thousand times since its revolving electrons, whose outermost orbits determine its normal effective volume, are all stripped off or ionized by the intensity of heat. Each electron is thus so endowed with energy that it moves about as an independent unit unrestricted to any atomic orbit. Thus a free gaseous state can exist in spite of much closer packing than would suffice at ordinary temperatures to reduce the matter to the state of liquid or solid.

DENSE STARS

This conception, if it be true, throws light on a long-standing astronomical mystery. There are known to be a few stars, like the *white dwarf* companion of Sirius, so small yet so massive that their density worked out to be of the order of fifty thousand times that of water—an absurdity it was thought, an impossible result, something radically wrong somewhere in the observations or calculations. But instead of finding something wrong with the calculations, Eddington's work suggests that the trouble lay in our thinking the result absurd, in our failure to realize the tremendous difference between the state of matter at terrestrial temperatures and at stellar temperatures.

GIANTS AND DWARFS

If, then, all the stars are in a true gaseous condition, it is necessary to modify all ideas and calculations based on the old point of view that the dwarf stars were not obeying the same laws of pressure,

volume, and temperature as the giant stars. Prof. H. N. Russell's famous Giant and Dwarf theory of Stellar Evolution suggested that a star begins its career as a very large mass of gas, highly inflated and much less dense than air. This would slowly contract by gravitational influence, growing hotter and hotter and brighter and brighter. This period would embrace its life as a giant star.

When contraction had reached such a point that, upon the old view, the gas laws could no longer be considered as even approximately representing the state of the star, then at this critical point of balance between mass, density, and temperature, further gravitational contraction would of necessity be accompanied by decrease of temperature and of luminosity. This period constituted the dwarf stage of a star's career. Now this theory is thrown into a new light by Eddington's results. If the mass of a star be constant throughout

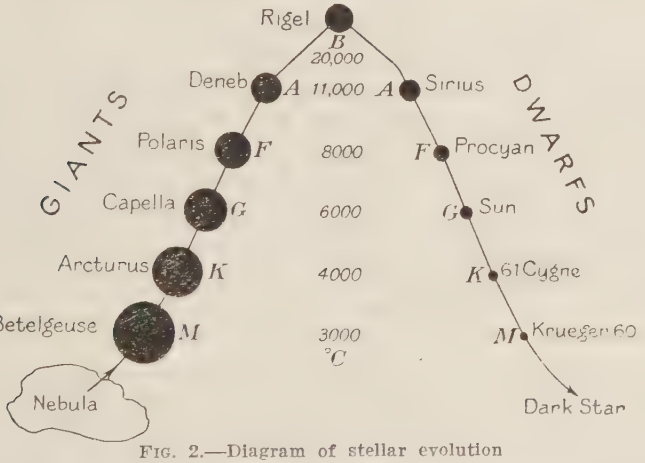

FIG. 2.—Diagram of stellar evolution

its life, Eddington's formula shows that there can be very little alteration in luminosity in spite of contraction, and hence the evolution of a single star as outlined above is an impossibility. If as an alternative interpretation the mass of a star is gradually diminishing, being actually consumed away to maintain the supply of energy which a star is continuously radiating, then Russell's theory of evolution may be retained as indicating the probable sequence of stellar change, but with this difference that, though the effective or surface temperature may decrease during the latter stages, the internal temperature will continue to rise.

LOSS OF MASS

A great deal thus turns on whether the mass of a radiating star can actually be considered to be diminishing. There are, furthermore, two ways of looking at this question.

One suggestion is that by collision of a very infrequent type between an electron and a proton (the ultimate particles of matter known to the physicist, carrying the unit electrical charges, negative and positive) their impact results in complete annihilation of their mass—that is, of the matter which they form—a definite amount of radiant energy being the equivalent result. This is highly speculative, there being no observed phenomenon in nature to prove definitely that such a transformation can take place; but it is theoretically possible, for matter and energy are essentially the same thing. Matter is one of many forms of energy and in the usual units of measurement of energy, the energy equivalent of a mass m grams of matter is $m\ c^2$ ergs where c is the velocity of light, 3×10^{10} cm. per second. In other words, one gram of matter represents a potential concentration of energy equivalent to nine hundred million million million ergs, or as more conveniently expressed, 9×10^{20} ergs; or one pound of matter embodies $1\times(186{,}000\times5{,}280)^2$ foot-pounds of energy—that is, 10^{18} foot-pounds.

The theory of relativity has shown mathematically, and it has been confirmed experimentally for fast moving alpha and beta particles, that what we term mass is really a property of matter that depends upon its velocity. Mass increases with increase of velocity, but this increase only becomes apparent when the velocity is so great that it becomes comparable to the velocity of light. The full expression for mass energy in the relativity theory is

$$mc^2 = m_0c^2 + \tfrac{1}{2}m_0v^2 + \tfrac{3}{8}m_0v^4/c^2 + \text{———}$$

Here the first term is the whole intermolecular energy of the mass at rest; the second term is its kinetic energy, or the energy possessed by it in virtue of its motion; the third and subsequent terms will be quite negligible for small values of the velocity v of the mass, but become appreciable one by one as the velocity v approaches the velocity of light. From this it follows that in order for the mass of a star to diminish as a result (or perhaps we should say as the cause) of its radiation, it is not necessary to postulate the annihilation of matter, but simply the loss in mass resulting from loss in velocity. From the above equation it can be seen that this might well be a tremendous reservoir of available energy.

The idea that continued stellar radiation might imply gradual loss in stellar mass was not new. It had been suggested some years ago by Dr. J. H. Jeans, but the facts above explained brought this idea forward with a new significance. Doctor Jeans saw that if this idea be really true, many astronomical problems are seen in a new light, and many investigations require reconsideration. This he has done and only recently has he published his results.

AGE OF SUN

One of the questions which has provoked controversy between geologist, physicist, and astronomer for many years is the probable age of the earth, an estimate of the age of the sun being, of course, an upper limit to the age of the solar system. Jeans attacks the problem from the new point of view, and his argument is as follows: The sun is radiating away its mass at the rate of about 4,200,000 tons per second and, if it were once as massive a star as Sirius now is, then it has been radiating for 7×10^{12} years. This means an age of at least a million million years, and is several thousand times greater than any previous estimate—a figure so great that it baffles comprehension, and staggers even the imagination.

GALAXY EXPANDING

There is an interesting consequence of loss of mass by radiation which has an important bearing upon our system and upon the galaxy of stars about us. If our sun be gradually diminishing in mass, the law of conservation of momentum requires that the planets move gradually off in ever expanding orbits. Similarly, if the mass of our galaxy as a whole be gradually diminishing, the stars must be opening out, spreading farther apart from the common center of gravity and therefore from one another. Jeans estimates that 10^{12} years ago this galaxy was packed sixty-four times more closely than it is at the present time.

BINARY STARS

This modifies various problems of cosmogony in a remarkable manner. The orbits of binary stars have long been a mystery, because no mutual force between two such stars was known which could account for their being in such eccentric and large orbits about their common center of gravity. Jeans points out that it is no longer necessary to look for such a force, that with the enlarged time scale for the galaxy (greater than 10^{10} years) outside influences become not only possible but very highly probable—that is to say, the normal orbits of a binary system may be perturbed by the gravitational pull of a passing star approaching more closely than is usual. The chance of such an influence being brought to bear upon a binary is greatly increased by the closer packing of the system in bygone ages. Basing his calculations upon the observed percentage of decidedly modified binary orbits and the probability of outside influence, Jeans obtains an estimate of the age of the galaxy which confirms his previous result of 10^{12} years.

MASS AND VELOCITY

A statistical study of the masses and the velocities of stars revealed a striking correlation, which though incomplete pointed toward equipartition of energy. No satisfactory explanation of this was offered until Jeans dispelled the clouds of mystery by showing that it is essentially the same problem as that just discussed. The mutual influences of the stars, originally sixty-four times as closely packed as now, have resulted in the course of 10^{12} years in bringing some measure of order out of primeval disorder. It is analogous to the behavior of a mixture of gases—if undisturbed by external influences the tendency would be for those molecules most massive to move most slowly while the lighter molecules moved with the greater speed, the kinetic energy or product of mass by velocity squared, tending to be the same for all the molecules. This also formed a basis, though of a truth a somewhat shaky basis, for again confirming the age of the galaxy as 10^{12} years.

SOLAR SYSTEMS

The nebular hypothesis of Laplace and the planetesimal hypothesis of Chamberlin have gone into the history of science as great and lasting monuments to their originators, both of whom were powerful and constructive thinkers. As a direct development from Chamberlin's hypothesis, Jeans some years ago worked out upon a rigorous mathematical basis his tidal theory of the origin of the solar system. In view of the contrast between his conclusions in 1919 and his present conclusions in the light of the researches under review, it is worth while to consider the tidal theory in some detail.

An analysis of the equilibrium forms of rotating fluids under various conditions amenable to mathematical treatment, revealed the fact that within a rotating gaseous mass there are no forces which could combine to produce a series of planets such as encircle our sun. Hence, following the lead of Chamberlin, Jeans called in the aid of a passing star to supply the force necessary to disrupt the parent sun. It is obvious that a close approach of one star to another would draw out tides, one on each side of the star considered, the tidal arm on the side nearest to the tide-producing star being slightly the greater, and therefore more readily drawn out to a distance producing its instability. The matter in this arm would then break away from the parent sun and follow orbits about the sun in directions governed by the direction of travel of the passing star. Condensation would gradually take place about any points in the tidal arm where there happened to be a local concentration of gas. Each of these nuclei would become one of the planets, and its orbit and other individual characteristics would be determined, in part at least, by

the influence of the "resisting medium" through which it moved, this medium being composed of the vast millions of gaseous particles scattered hither and thither into space about the sun by the cataclysmic disruption of the tidal arm.

The formation of satellites by the planets is again an evidence of tidal action, but in this case the sun itself was the tide-producing agency which caused the disruption of the planets when each passed its perihelion for the first time. That some satellites so formed eventually became detached from their parent planets to be captured by other planets is one of the interesting results of the action of the resisting medium.

Dr. Harold Jeffreys has recently proposed several modifications of the above tidal theory. The outstanding point of difference is that Jeffreys limits the size of the ancestral sun to 40 million kilometers in diameter, whereas Jeans had presupposed a much less dense sun of diameter 8,000 million kilometers; the former figure is approximately the diameter of Mercury's orbit, the latter figure is greater than the diameter of the orbit of Neptune. The evidence in favor of the smaller figure seems to be fairly strong.

UNKNOWN PLANETS

The point of interest in both these forms of the tidal theory is that they led to the belief that our solar system was possibly unique in the galaxy of stars, because the chance of two stars approaching closely enough to produce tidal disruption—namely 10^{10} kilometers—was only once in 10^{10} years, which was the whole age of the galaxy then considered possible. With the much greater time scale now proposed by Jeans, and considering also the much closer packing in those early millions of years, the probability of the close approach of two stars becomes decidedly great. Hence the conclusion now reached by Jeans is that of the myriad stars we see about us—not the majority—but a considerable number are probably suns to a family of planets. Like our own solar system in many respects, these numerous other systems may be, yet differing probably from it and from one another in all the details. Whether upon some favored planets in some of these many systems there have been developed physical conditions as on this earth, rendering them fit cradles for the advent of life we know not, and it is beyond the scope of the mathematical physicist and astronomer to speculate further.

STABILITY OF GALAXY

An investigation of very great interest has been carried out during the last year by Dr. Ludvik Silberstein on the question of the

permanence of star clusters, in particular, the great star cluster or galaxy near the center of which our solar system finds itself. Silberstein bases his calculations upon the four-dimensional space-time relations of de Sitter, and from this starting point he last year deduced a relation which could be evaluated in terms of observed astronomical data in such a way as to give a numerical value for an invariant characteristic of spacetime called by the mathematician the radius of curvature. This quantity, symbolized by R, has the finite value of 10^{12} astronomical units, that is 10^{12} times the distance from earth to sun. This theory, with the consequent value of R, has not been universally accepted, but this does not detract from the interest of the subsequent reasoning by which Silberstein deduces a criterion of stability in terms of the total mass of a system of material bodies (molecules or stars) and the radius of the system. Associated with any given mass there is a critical distance. If a star be at a greater distance than this critical value from the center of gravity, its orbit will of necessity be a hyperbola. This means that sooner or later it will desert the system forever. On the other hand, if its distance from the mass center be less than the critical value it will describe an elliptic orbit, thus remaining indefinitely within the system.

This criterion has been applied to those globular clusters far out in space beyond our own galaxy, for which the astronomer has been able to form estimates of their size and mass. They are found to be considerably less massive than our galaxy and very much more closely packed, so closely packed that the calculated critical radius is much greater than the dimensions of the clusters, which may, therefore, from the point of view of this theory, be considered as stable aggregates of stars.

The reverse is the case of our own galaxy. Much too widely scattered for its mass, its radius exceeds the critical value for stability, and therefore this theory predicts that it will suffer from what Doctor Silberstein terms "hyperbolic desertion" until its ranks be reduced and its volume diminished to such an extent that the criterion might perchance be satisfied. In its present form it is, like the Roman Empire, far too inflated to be enduring.

Densities can be treated in a similar manner. Silberstein evaluates the critical density of matter in space in terms of his finite curvature invariant R, the gravitational constant and the velocity of light—three fundamental quantities in this complex universe. Any aggregation of matter of less than this critical density will be unstable and tend to dissipate, whereas any aggregation of density exceeding this value will be in a state of stability. The galaxy of stars in which our system finds itself is estimated to have a density fifty-two times too small to satisfy the conditions for permanence.

Having surveyed the future, let us, in the light of this same theory, glance backward in an endeavor to trace the origin of a stellar cluster. Silberstein considers the possibility of a gaseous mass or nebula giving rise to millions of individual concentrations of matter, and thus forming the individual stars of a cluster. This was essentially the primary postulate of Laplace, though he was considering the relatively minute case of a nebula giving rise to a solar system—an impossible hypothesis in the light of modern knowledge. But as an explanation of the evolution of a small galaxy of stars, like many of the star clusters revealed by the telescope, it is by no means to be discarded—it may well be the true solution of the problem, as was pointed out by Jeans some years ago. When, however, an attempt is made to explain the origin of our galaxy in this manner, it is found to be incapable of satisfying all the conditions. Our galaxy, to quote yet another analogy taken by Doctor Silberstein from the history of mankind, must have developed, like the far-flung British Empire, by the aggregation into one conglomerate whole of many remnants of previous systems, systems long since scattered to the four winds.

Guided by some of the great thinkers of to-day, our thoughts have traversed æons of time, contemplating some of the changes taking place with majestic deliberation throughout the vastnesses of space. "Time rolls his ceaseless course." A million million years suffice for the birth of a star and its early development; a few hundred thousand years will tell the tale of the life of mankind upon this planet; and as for man, an individual man, the years of his life are three score years and ten, and yet such is the power of a great mind that, despite the brevity of its allotted span, it can wrestle with the problems of nature and learn something at least of the immensities of space and time.

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CERTAIN ASPECTS OF HIGH-PRESSURE RESEARCH[1]

By Prof. P. W. Bridgman, Ph. D.
Harvard University

As some of you know, I have been occupied for a number of years in determining the effects of high hydrostatic pressure on a number of physical properties. To-day, I propose to stop for a minute for a general stock taking, to outline briefly some of the results obtained and to suggest partially their possible significance. I am impelled to do this because the variety of subjects touched by this high-pressure research is so great, and the character of the information obtained in many cases so special, that the whole effort is likely to appear without general scheme or significance. But I believe that different limited aspects of the subject will be of interest to different individuals; by presenting to you the general outline, I hope to make it possible for any individual to become aware of those aspects of the work which may be of special significance to him.

My general attitude in my investigation has been that high pressures are a tool which may be significantly applied to the discussion of many different problems. It is not usual, however, for an experimenter to devote himself to exploiting a single tool of research. I am somewhat in the position of a small boy with a new jackknife who rushes about trying it on every conceivable object. Doubtless the more mature method is to maintain a tool box from which one might take the jackknife when one has to sharpen a pencil, or an augur when one has to bore a hole. I may suggest, in partial extenuation of my attitude, that there seem to be very few jackknives in the world, or at least very few people who seem willing to use them, and there really does seem to be a certain amount of whittling that needs to be done.

The kind of problem which can be attacked most successfully by the use of high pressures is not that which is now most interesting to most physicists, nor which appears to be most fundamental. This tool is not particularly adapted to probing questions of the constitution of the atom and particularly of the nucleus, but is better

[1] Address delivered Thursday, Sept. 18, 1924, on the occasion of the celebration of the centenary of the founding of The Franklin Institute. Reprinted by permission from the Journal of The Franklin Institute, Philadelphia, August, 1925.

adapted to the larger scale atomic and molecular phenomena. There are, of course, occasions when the behavior of matter under high pressures intimately involves the inner structure of the atom, but in general the pressures with which I am concerned are too small to produce large changes in the atoms themselves. We are concerned here with pressures from 10,000 to 20,000 atmospheres. These are capable of producing comparatively large and significant changes in the properties of many substances, but they can not, of course, be compared with the pressures of perhaps billions of atmospheres which occur in the interior of the stars, and which are supposed to be a factor in atomic evolution.

The significance of high pressure as a tool of atomic research lies in the extreme simplicity of the change it produces in the external conditions, merely pushing the atoms closer together so that they are compelled to give a somewhat more intimate account of their own inmost selves. The changes produced by pressure are obviously much simpler than those produced by a change of temperature. No one regards our understanding of a phenomenon as satisfactory unless we are able to give some account of the changes produced by temperature; still less should we be satisfied if we can not account for the changes produced by pressure. Further, by combining the effects of temperature and pressure, we extend enormously the field in which we may look for phenomena suggestive for our theories, for the field is now two instead of one dimensional.

It is not necessary to apologize for activity in atomic phenomena, even if they are not on the extreme end of the exploring line, because they are the phenomena which are perhaps of most immediate concern to us in daily life, and we have as yet hardly begun to understand them. The extent of our ignorance may be emphasized by the fact that none of our theories is able to predict accurately any of the high-pressure phenomena which I shall summarize, in spite of their extreme simplicity.

Perhaps the most fundamental of the changes produced by pressure are those of volume itself. I have measurements of the compressibility of 5 gases, 15 liquids—most of them simple organic liquids, but including water and mercury—and some 45 different solids, 35 of them metallic elements, several minerals, and several varieties of glass. I may mention here also the compressibility of 11 of the alkali halides determined by Dr. J. C. Slater, in the Jefferson Laboratory. All of these compressibilities have been determined at several temperatures, so that we know the effects of pressure on thermal expansion. The melting curves of 37 substances, including metallic elements and organic compounds have been determined. These melting measurements include a determination of the change of melting temperature when pressure is raised, the change of volume

on melting, the latent heat of melting, and in many cases the difference of compressibility between liquid and solid. The effect of pressure on the polymorphic transitions of some 30 substances has been investigated, including organic and inorganic compounds and the very interesting case of water. This investigation has involved the study of 69 transition lines and 21 triple points. On these transition lines the change of transition temperature with pressure has been determined, and also the change of volume, the latent heat, the difference of compressibility (which gives information about the difference of thermal expansion and specific heats), and the effect of pressure on velocity. In addition to these 30 substances, about 100 others have been examined and no new polymorphic forms have been found. The effect of pressure on electrical resistance over a range of temperature has been determined for 45 metallic elements in the solid state, 8 in the liquid state, and for 7 alloys. The effect of pressure on thermal e. m. f. has been measured for 18 metallic elements and 2 alloys. The effect of pressure on the thermal conductivity of 11 solid metallic elements, 6 minerals, and 15 liquids (all organic except water) has been measured. Finally, a few observations have been made on the phenomena of rupture under high pressure.

What now is the general nature of the facts found, and some of their implications? First, consider the facts with regard to changes of volume. At high pressures there is no essential difference between a gas and a liquid. Under 12,000 kg. the changes of volume of ordinary nonmetallic liquids range from something like 20 per cent for water and 33 per cent for ether up to those of hydrogen and helium, which are the most compressible substances investigated, and which, under 12,000 kg. at ordinary temperatures have a volume less than half that which they have when frozen solid at atmospheric pressure by temperatures close to 0° Abs. Under these pressures there is a very great change in properties. The thermal expansion drops to less than one-fourth of what it is ordinarily, and the compressibility drops to one-fifteenth; both of these changes are very much greater than the changes of volume. The fact that compressibility and thermal expansion drop off so greatly for comparatively small changes of volume suggests that these must be intimately connected in some way with the empty spaces between the atoms. All of the organic liquids behave roughly alike, so that an average of them furnishes us with a sort of ideal liquid, analogous to the familiar "perfect" gas. This ideal liquid has one curious property; above a certain pressure the ordinary behavior of thermal expansion reverses itself, and the liquid is more expansible at the low rather than at the high temperatures. In addition to the broad features, which are alike for all liquids, each

individual shows small and perfectly characteristic divergences from the mean, which do not become conspicuous until the highest pressures are reached. These suggest differences between the different kinds of atoms or molecules, roughly corresponding to differences of shape. If an atom has a "knob" on it (local inequality in its force field), it will interfere with its neighbors and produce perceptible differences of behavior when the atoms are pushed close together by high pressure. On the other hand, it is interesting that water, which under ordinary conditions is a highly abnormal liquid, under high pressures loses its abnormalities and returns to normality.

The kinetic theory of gases, extended to include the behavior of liquids up to a few hundred atmospheres around the critical point, has engaged almost exclusive attention up to the present time. There is, so far as I know, no theory of liquids that, with any approach to success, attempts to picture how the molecules in a liquid behave when pushed into such close contact that there is considerable mutual interference.

The changes of volume of the solid elements (metals mostly) are in general much less than those of liquids, but they are nevertheless significantly large, as in most cases it is possible to reduce the volume by pressure to considerably less than it would be if the metal were deprived of all heat motion by being cooled to absolute zero at atmospheric pressure.

Some of the metals are highly compressible, and cæsium, in particular, loses more in volume at high pressures than ether. There is a characteristic difference between liquids and solids in that solids do not lose their compressibility nearly as rapidly at high pressures. We would expect a difference of this sort; in solids, the atoms must retain their regular crystalline arrangement at high pressures, so that the free spaces around the edges and corners of the molecules are never occupied and hence play a relatively small part in the phenomena of compression. In a number of solids it seems that the persistence of compressibility at high pressure can be explained only by a compressibility of the atoms themselves. There is here an important problem for quantum theory: To formulate the quantum conditions when the electronic orbits interfere with each other as much as they must in a strongly compressed solid.

There is no adequate theory to explain the properties of metals. In fact, the general nature of their structure is less well known than is that of the structure of certain salts, compounds of two elements. The data on compressibility now give us the means of finding the first three derivatives of the forces between the atoms of a metal.

As a physicist, I am sanguine that the mathematician can go far toward reconstructing the function if he knows its first three derivatives, and we may hope at any rate that these data will make possible a more adequate description of the force field about an atom, even if they do not completely determine the mechanism.

It has been stated that compressibility becomes less at high pressures. This is what we should expect, because, as the atoms are squeezed closer together, it seems natural that they should resist more strongly attempts at closer propinquity. I have found, however, a significant exception in quartz glass and several varieties of ordinary glass in which SiO_2 is a prominent constituent. These become more compressible at high pressures. This can not but be significant; our theories must explain why it is that, under some conditions, the atoms resist compression less strongly the closer they are pushed together. It is natural to seek to establish a connection with the fact that these abnormal substances are amorphous instead of crystalline, and that they would doubtless crystallize with a decrease of volume.

The probable effect of pressure on melting temperature was for a long time a matter of controversy. Early views were strongly influenced by the striking critical phenomena between liquid and vapor, and it was supposed by many that there would be found a critical point between liquid and solid such that above this point liquid and solid might be made to change from one into the other without discontinuity. A later rival theory, strongly defended, was that of Tammann, who supposed that there was a maximum melting temperature above which a liquid could not be forced to freeze by any pressure no matter how high, and below which the liquid might be frozen and the solid melted again by a sufficiently high pressure. The experimental difficulty in settling this question was that the available pressure range was not sufficient. But with the data now at hand, we may, I believe, regard this question as settled. It appears from the evidence of 37 substances that there is no experimental reason to think that the melting curve does not rise indefinitely, at a continuously decreasing rate, but nevertheless so that at any temperature a pressure can be found high enough to freeze the liquid to the solid. There is no connection whatever between the melting phenomena and the ordinary critical phenomena of liquid and vapor; the amorphous phase may be frozen by sufficient pressure either above or below the critical temperature. This is, after all, the natural result. It would seem as if one ought, by pushing the atoms close enough together, to be able eventually to undo the disorienting effect of an increase in the energy of temperature agitation. A continuous passage from a liquid to a solid was most difficult to visualize with our concept of a liquid as a haphazard aggregate of molecules,

and of the solid as consisting of the same molecules regularly arranged.

The discovery of the true character of the melting curve is of evident importance for geophysics.

In addition to an indefinitely rising melting point, the measurements showed that solid and liquid become more and more alike in volume at high pressures, but that the latent heat absorbed on passing from solid to liquid is little changed. It is furthermore universally true that the liquid is more compressible than the solid.

This is natural enough for normal liquids, but is not so obvious in the case of ice, which has a volume larger than that of liquid water, but is less compressible. All these facts must be explained by the future theories, but nothing essentially new is involved here; when we have an adequate theory of the solid and the liquid state separately, the correct explanation of the melting phenomena will automatically follow.

Another interesting fact brought out by the measurements on water and some other substances which crystallize in two or more modifications is that in the liquid there may be nuclear structures of considerable complexity capable of persisting for days. The liquid is not the simple thing that it may appear to a casual glance, but, at least under some conditions, it may carry concealed within it traces of its past history imperceptible to ordinary means. The existence of these structures in the liquid is now being demonstrated by X rays, but the extraordinary persistence of the individual structure can not be shown by such means.

One minor way in which the pressure tool may be of value is in determining latent heats of melting. A calorimetric measurement is admittedly difficult. By measuring the melting pressures corresponding to two melting temperatures near the normal melting point and determining the changes of volume, one has an indirect measurement of latent heat which is often far preferable to a direct measurement. The pressures involved are not high—only a few hundred atmospheres—and the apparatus is so simple that it may be readily constructed.

Contrasted with the phenomena of melting are those of polymorphic transitions in the solid state. These are of all degrees of complexity and are governed by a few simple rules. No cases have been found of a critical point between two solid modifications; this doubtless corresponds to some essential physical necessity, for it is hard to see how one kind of space lattice which is characteristic of one crystalline modification can change, without discontinuity, into some other space lattice characteristic of another crystalline modification. Except for this, we may apparently have nearly every kind of behavior. Under varying conditions of pressure and tem-

perature, transitions may take place with no volume change, and others with no latent heat. As pressure rises, the slope of the transition line may either rise or fall, while the slope of the melting curve always falls. There is a surprisingly large number of cases analogous to that of water and ice, in which the modification stable at the higher temperature has the smaller volume. We might be inclined to think of this as an abnormal state of affairs, and might expect that high pressure would tend to wipe it out, but such is not the case, and these ice-type transitions persist at least to pressures beyond our present reach. Another surprising fact is that in the majority of cases the modification with the smaller volume is the more compressible. This is the same behavior as that shown by water and ice, and can not help being of significance for atomic structure. It means that the atom has outlying parts which have centers of force of strength sufficient, in conjunction with the outlying parts of other atoms, to build up an open-work structure, and that these outlying parts have more than usual stiffness, so that the resultant open-work structure has a lower compressibility than the more dense structure which the atoms are forced to assume by a pressure sufficiently high to push the outlying centers of force out of register. From some points of view, the thought of atoms as having "knobs" is certainly suggestive, although so crude a picture is repulsive to some persons.

One feature of the behavior of polymorphic forms, which is of great significance, may be studied to advantage with the high-pressure tool. This is the speed with which one modification transforms itself to another. A particular advantage of this tool is the nicety and rapidity of control which it offers. Changing the pressure on a two-phase system is equivalent to changing the temperature, but, whereas the actual temperature can be changed only slowly and nonuniformly throughout the interior of the apparatus, and considerable time is required for attainment of equilibrium, the effective temperature may be changed instantly and uniformly by any desired amount by a stroke of the pressure pump. By changing the conditions in this way in the immediate neighborhood of a transition point, I have studied a considerable number of solid transitions under pressure. There is an essential difference between a change from one solid to another and that from a solid or a vapor to a liquid. If a vapor and liquid or solid and liquid coexist, then at any definite temperature a single definite pressure of equilibrium will be automatically established. The ordinary kinetic mechanism makes this understandable.

Equilibrium between vapor and liquid, for example, is maintained by the action of two streams of matter, one continually condensing on the liquid from the vapor, the other continually evapo-

rating from the liquid into the vapor. When the velocity of the two processes is the same we have equilibrium, and if equilibrium is disturbed the two processes restore it. But with two solids the behavior may be (although not necessarily) quite different, in that two solids may coexist indefinitely in contact at a definite temperature anywhere within a range of pressure. This is different from the familiar persistence of a modification in a region of thermodynamic instability which involves viscosity. In such a system it is usually supposed that equilibrium will be automatically produced if the temperature is raised to the point of thermodynamic equilibrium and the two phases are in contact. The mechanism by which a definite equilibrium is automatically set up does not exist in the solid. In the solid it is probably near the truth to imagine the atoms as tied to certain mean positions of equilibrium and as vibrating about these positions, but never departing from them by more than a definite amount. In the liquid or vapor, on the other hand, we have something like Maxwell's distribution of velocities, and it is possible to find a few atoms with any velocity that we please, no matter how high above the mean. Suppose now two modifications of the solid to be in contact. If an atom is going to change from one modification to the other it will have to free itself from its first position before it can settle down into the second. If the act of freeing itself from the first position involves too much of a departure from the mean, the atom will not be able to make the change, even if the new position, when once attained, is a position of greater stability. But by a sufficiently large change of external conditions the atom may be helped to free itself from the first position, and so attain the second. I have studied in some detail the way in which the width of the "domain of indifference" varies with pressure and temperature, and also the variation of the velocity of transition outside the domain. Both show large and very different sorts of variation for different substances.

At present we have absolutely no theory of polymorphism; we are acquiring by X-ray analysis a descriptive knowledge of the different atomic arrangements of polymorphs in some cases, but we have no explanation to offer of why, under some conditions the atoms build themselves into one kind of structure and sometimes into another. For instance, who has any adequate explanation of why diamonds are so rare and graphite so common? There is here a curious example of the indirect progress that physics sometimes makes. It would seem to be a much simpler problem to explain the ways in which an atom may combine with others of its own kind than with those of a different kind, whereas in fact we have at least the beginnings of an understanding of a great many chemical compounds, but can not claim anything of the kind for polymorphs. I can not help feeling that an understanding of the great multiplicity

of the phenomena of polymorphism under high pressures will be of assistance in understanding this fundamental matter, if only once somebody can find the loose end of the skein, and I even hope that it may be helpful in finding the loose end.

One particular transition produced by pressure is so interesting that I shall mention it in detail. Under proper conditions of pressure and temperature, ordinary yellow phosphorus is transformed into a black variety much like graphite in its properties, and of a density nearly 50 per cent greater than that of the parent yellow phosphorus. The change is irreversible and permanent, and is the only example of such a permanent change produced by high pressure that I have found. The mechanism of the change is not at all understood, although a number of attempts have been made at explanation. The great difference of density points is something unusual. I wish to direct special attention to the conditions initiating the change from yellow to black. For a time varying from 10 to 30 minutes before the change occurs, some preliminary change takes place throughout the entire interior of the mass of phosphorus, which is accompanied by a slight loss of volume, and which proceeds at an accelerated rate until the entire structure becomes unstable and collapses into the new modification. This preliminary change can not be produced in the usual ways by external agents. For instance, we can not inoculate a mass of yellow phosphorus with black and thereby either hasten or delay the transformation. There is nothing else that I know of like this behavior. Certainly the ordinary formation of a new phase out of one that has become unstable by the formation of nuclei and the growth of these nuclei at a definite rate has nothing in common with this.

The electrical resistance of metallic elements in general decreases under pressure, the rate of decrease itself decreasing by a sort of law of diminishing returns as the pressure rises. The magnitude of the decrease under 12,000 kg. varies from 1 per cent or less for metals like cobalt and tungsten to more than 70 per cent for potassium and rubidium. There is no simple connection with the change of volume, as the change of resistance is of the order of tenfold greater. The resistance of a few metals increases under pressure, and it is true of all of these that the rate of increase itself increases with the pressure. I have now, in addition, two unique metals: Cæsium, whose resistance at first decreases but later passes through a minimum and then increases; and antimony, whose resistance, at right angles to the trigonal axis, at first increases, but later passes through a maximum and then decreases. The effects of pressure are thus much more complicated than those of temperature (which are nearly the same for all metals), but they may, I believe, be even

more suggestive in formulating a theory of resistance. Some important relations are brought out by the pressure tool that might not otherwise be known. Thus, the fact that pressure increases the resistance of solid bismuth, which is abnormal, but decreases that of the liquid, which is normal, strongly suggests that the abnormal behavior of solid bismuth is connected in some way with a peculiarity of the crystal structure. But, on the other hand, the fact that pressure increases the resistance of both solid and liquid lithium shows that the abnormality is in some way more deep-seated for this metal and is doubtless connected with some characteristic of the atom as a whole. The pressure effects bring out the fact that the conduction mechanism is not as simple as we might have supposed from the fact that the temperature coefficient of all metals is nearly the same.

There is, of course, no adequate theory of metallic conduction; the classical free electron theory has had to be given up, and there is no satisfactory substitute. I have myself made an attempt at finding the significance of the various pressure effects, and have been led by them to a very general conception of conduction which I believe must be incorporated into the finally accepted theory. This conception is that the atoms play an essentially positive part in conduction and, in some way which we do not at present understand, make it possible for electrons to pass from one part of a metal to another. According to the classical conception, the rôle of the atoms was entirely secondary and negative; the atoms were the source of the free electrons, but, having once provided the electrons, their rôle was merely that of trouble makers, getting in the way of the electrons and preventing them from moving about as they wished. But it now appears that the electrons can not drift about without the intervention of the atoms. It is as if the atoms hand on the electrons from one to another when they are lined up in certain ways, or as if there were tracks between the intricate maze of quantum orbits within the atom, along which the conduction electrons may travel, so that there is an opportunity for long flights by the electrons when the tracks are properly aligned. All of the normal and abnormal effects of pressure are understandable in terms of a picture like this if we only suppose that the atom itself, when brought into close proximity to its fellows, behaves in the unsimple way that the facts of compressibility and polymorphic transition compel us to suppose. It is natural to suppose that these definite tracks are in some way connected with quantum conditions, and perhaps with high quantum numbers, but the details are too complicated for our working out at present.

The effects of pressure on thermal e. m. f. I have not attempted to incorporate into any definite theory, but they do suggest one

important point of view. The pressure effects are complicated, there being maxima, minima, and complicated temperature effects. We do not in general expect that so simple a thing as a hydrostatic pressure will produce complicated effects, unless these effects involve a complicated mechanism. I have therefore drawn the conclusion that the thermal e. m. f. mechanism must be comparatively complicated, and not the simple thing supposed by the classical theory; this I have considered sufficient justification for not attempting to explain thermal e. m. f. in a first simple theory of the electrical properties of metals.

We pass now from the electrical properties to the thermal properties of metals. It is well known that there is a close relation between electrical and thermal conductivity, which is expressed in the law of Wiedemann-Franz. The behavior of thermal conductivity under pressure shows that, although the relation may be close, there are other factors which have been insufficiently considered.

The thermal conductivity of most metals increases under pressure, but that of some decreases, and for the most of them the change of electrical conductivity is greater than that of thermal. The reason for the difference is doubtless to be found in the contribution made to thermal conductivity by the atoms as distinguished from the electrons; but a consideration of numerical values suggests that the atomic part may be greater than has been supposed.

The thermal conductivity of minerals has been measured under pressure, a matter of importance to geophysicists. It has been found that in general the thermal conductivity of minerals increases under pressure, but the increases are not large enough to demand serious modification in our ordinary geological arguments, except possibly at great depths.

The effect of pressure on the thermal conductivity of liquids is interesting because it is so large; 12,000 kg. increases the conductivity by from two- to threefold. In speculating as to the reasons for this, it appears that there is a very intimate connection with the velocity of sound. Entirely apart from the pressure effects, a reexamination of the old facts with the new bias given by the pressure measurements has shown that the main mechanism of thermal conduction in a liquid is of surprising simplicity, being a sort of combination of the kinetic mechanism of a gas and the elastic wave mechanism of a crystalline solid. If we conceive of each molecule of the liquid as possessing the kinetic energy of temperature agitation demanded by kinetic theory, and handing this energy on to its neighbors with the velocity of an elastic wave of small dimensions—that is, with the velocity of sound—we shall account almost entirely for the thermal conductivity of ordinary liquids.

Apart from the various effects which have been measured accurately, results obtained under high pressures suggest other new points of view. Thus in the preliminary work, before I had found out how to make tight joints, or had learned what the capabilities of steel cylinders were in withstanding pressure, I observed a number of different types of rupture under unusual conditions, which are of some interest to the engineer. By selecting results under different conditions, it was possible to show that none of the ordinarily accepted criteria of rupture are valid except under restricted circumstances. The general, and therefore the significant, conditions of rupture are yet to be formulated.

Finally, we may glance at what remains to be done. Although the most readily obtainable results have been secured, the subject has not been more than begun. It becomes more and more impressed upon me that significant results are to be found in little frequented places, as, for instance, by working on materials that have extreme properties or in going to extreme temperatures. Thus, quite recently, this has led me to determine the properties of cæsium, the most compressible of the metals, with the extremely suggestive discovery of minimum resistance. The same sort of thing is to be done with many other materials of unusual properties. The extension of these high-pressure results to temperatures near the absolute zero, where phenomena assume an unwonted simplicity because of the absence of temperature agitation, will doubtless be of extreme importance. Results just as important lie also at high temperatures, a most difficult field, which the Geophysical Laboratory is skilfully attacking. Interesting special results may be found; the will-o'-the-wisp of manufactured diamonds is always before us. Without doubt, important practical developments lie in a field as yet practically untouched, that of organic, colloidal, and biological chemistry. It was shown a long while ago, at the West Virginia Agricultural Experiment Station, that high pressures will sterilize milk. I have found that high pressures in the cold will also coagulate egg white, or the proteids of meat. Here is an enormous field untouched. We ought to know the effect of pressure on every substance of biological significance, just as we now know the effect of an elevation of temperature, and we may anticipate that important changes or combinations may be produced by pressure, just as they are now produced by temperature.

On the purely physical side, the field is immense. Entirely apart from new experimental knowledge, we can not be satisfied with any theory which does not adequately explain the effects of high pressure already known, and conversely I venture to hope that these phenomena of high pressure may play an increasing part in formulating more adequate theories of the structure of matter.

LIGHTNING AND OTHER HIGH-VOLTAGE PHENOMENA[1]

By F. W. Peek, Jr.

General Electric Company, Pittsfield, Mass.

[With 11 plates]

I. Introduction

For a number of years the author has been actively engaged in research in various high-voltage phenomena. This work has been done from the standpoint of pure research to determine fundamental principles and from the standpoint of practice to better the insulation of apparatus, to extend transmission voltages, and to determine means of protecting transmission lines and buildings from lightning. By combining pure and applied research a much broader view is obtained, and there is no better test of theory than to attempt to apply it to practice in a simple way. It will often be found that essential factors have been overlooked.

In the following discussion the practical as well as the theoretical viewpoint will be kept in mind.

II. High-Voltage Phenomena

High electric pressure or voltages are necessary for economical long distance transmission, but when such voltages are used without proper precautions in design the energy may leak away from the lines with a hissing noise in the corona. The corona is a beautiful crown of light surrounding the conductors and is a manifestation of the ions and electrons moving in the electric field.

The sparking distance is also of theoretical and practical importance.

Laws of corona, sparking curves, etc., were established at the comparatively low voltages of the order of 250,000. These were successfully applied to 220,000-volt transmission lines.

III. Research at High 60-Cycle Voltages

Within the last few years the work has been extended to voltages of 1,000,000 volts above ground, 1,500,000 single-phase and over

[1] This report is a nontechnical summary of two papers, High Voltage Phenomena, Journal of Franklin Institute, January, 1924, and Lightning, an address delivered at the centenary of the Franklin Institute, September, 1924, and in the Journal in February, 1925. Complete technical information and data will be found in these papers.

1,000,000 3-phase 60-cycle root mean square values.[2] It was of interest to find if the laws and curves established at the lower voltages still applied at the very high voltages. The results of some of the very high 60-cycle tests will now be described.

CORONA

When voltage is applied between certain types of conductors, as, for instance, parallel wires a considerable distance apart compared to their diameters, and is gradually increased, a crown of light suddenly bursts out around the conductors at a very definite critical voltage. The light is accompanied by a hissing noise. This is called corona. As the voltage is increased, the corona extends farther and farther out until finally a spark extends from metal to metal. The air is said to be ionized in the corona brush. The sudden outburst occurs when the voltage gradient at the conductor surface, where it is greatest, is sufficient to bring the ions and electrons up to sufficient velocity in their mean free path to produce others by collision with atoms. Certain chemical changes take place in the air in the formation of ozone and nitrous oxides. Corona and brush discharges are the same phenomena. In fact, corona and spark-over are also the same. The brush or corona are sparks to space. On relatively large electrodes placed close together, the intermediate corona can not form and the first evidence of over stress is a spark between conductors. The reason for this is known. With certain conductor configurations any increase in the conductor diameter tends to reduce the stress. The corona extends out and stops when the diameter is such that the stress is below the breakdown stress. With other types of electrodes, an increase in diameter tends to increase the stress. A brush once started must, therefore, extend directly between electrodes. The first type is changed into the second type with increasing voltage and the resulting extension of corona.

Corona starts at a very definite voltage. Several years ago a law was established for calculating this critical starting voltage for parallel wires based upon tests up to 250,000 volts. The factors determining the critical voltage are diameter, spacing, roughness of surface, and temperature and barometric pressure. The diameter of the conductor is the most important factor. A law was also established to predetermine the loss caused by corona. There is no appreciable loss until the critical voltage is reached. The loss then increases as the square of the excess voltage above the critical voltage.

[2] The single-phase tests have just recently (Oct. 8, 1925) been carried to approximately 2,200,000 root mean square or over 3,000,000 crest.

The mechanism of the corona is of extreme theoretical interest. There is also a practical interest because the laws of corona are very important in the design of high-voltage transmission lines. It is important to select the conductors so that a large percentage of the energy is not lost in the corona. A physical idea of what this means may be of interest. A 220,000-volt transmission line requires a conductor about 1 inch in diameter to prevent corona loss, while a million-volt line would require a conductor about 6.5 inches in diameter.

High voltages are economical when there is considerable power to transmit a considerable distance; 220,000 volts is economical when power of the order of 50,000 to 100,000 kilowatts is available to transmit distances of the order of 200 miles. With a million volts it would be possible to transmit 3,000,000 kilowatts 1,000 miles with about 12 per cent loss, using copper section equivalent to the 1 inch, 220-Kv. cable. The copper would of necessity be put in the form of a hollow tube to obtain the 6.5 inches diameter required by corona loss. There is, at present, no apparent economic need for 1,000,000-volt transmission.

The laws of corona established at the lower voltages were found to hold at the higher voltages.

Figure 1 shows the corona discharge from one of two parallel wires, while Table 1 shows good agreement between measured and calculated corona starting voltages for different electrodes.

TABLE 1.—*Corona on parallel brass tubes (60 cycles).*

Spacing		Visual corona voltages Kv. effective. $\delta=1.00$	
Inches	Cm.	Calculated	Observed
DIAMETER 3.5 INCHES=8.9 CM.			
75.5	192	790	730
111.5	283	876	895
147.5	375	915	915
183.5	466	990	990
DIAMETER 1.75 INCHES=4.45 CM.			
73.7	188	490	490
109.7	275	538	560
145.7	370	568	600
183.5	463	604	675
DIAMETER 1.0 INCH=2.54 CM.			
73	185	340	370
109	277	364	380
181	460	402	415

SPARK-OVER

The sparking distance between electrodes has been used for measuring high voltages.

A study of sparking distance is also of considerable theoretical interest and of practical interest in electrical design. It is necessary to know the sparking distances in order to supply sufficient clearances. The actual length of the spark for a given voltage depends upon the electrodes used and the temperature and barometric pressures.

A given voltage will spark the greatest distance between needle points and the minimum distance between planes and large spheres.

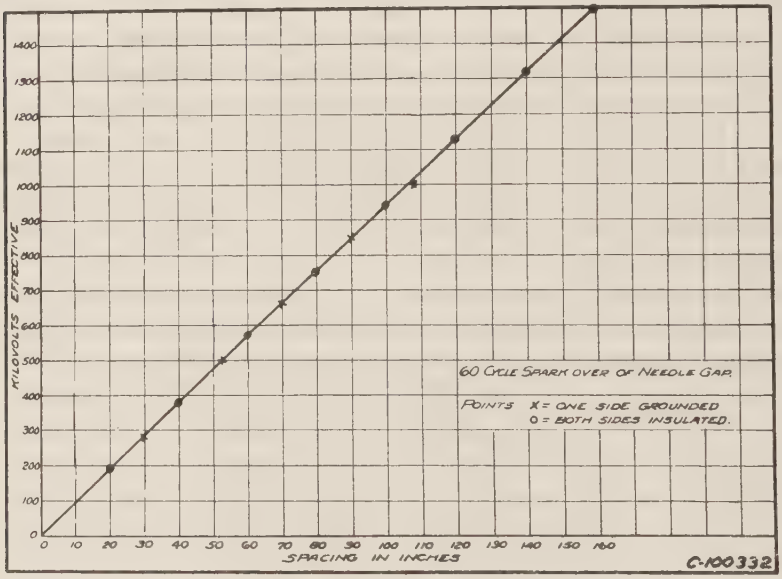


FIG. 2

This follows because the electrical stress is very unevenly distributed on the dielectric for needles and quite evenly distributed for spheres. For needles, the stress is greatest at the points where a corona brush always occurs at voltages much lower than the sparking voltages.

Tests at the very high voltages show that the laws and curves established at the lower voltages still hold. This is best illustrated in the curves that follow.

NEEDLE GAP

The needle gap spark-over curve is given in Figure 2 up to 1,500,000 volts effective. It will be noted that the curve is continuous from the low to high voltages. There is considerable variation in

this curve with atmospheric conditions. Figure 3 shows a single-phase spark-over at 1,500,000 volts.

SPHERES

The spark-over voltage curve for spheres is given in Figure 4. The values follow the equation established at the lower voltage.

INSULATOR SPARK-OVER

Figure 5 gives the spark-over values for standard 10-inch disk-suspension insulators. The curves are continuous from the lowest voltage to the highest voltage.

THREE-PHASE ARCS

Power is usually transmitted three-phase. Investigations were made of three-phase arcs. The standard arrangement was to place the three electrodes in the corners of an equilateral triangle.

The pecularities of the three-phase arc and corona are that the voltages are usually lower than for single-phase; the spark forms in a Y if there is no dissymetry; the spark does not take place at the instant of maximum voltage between conductors but at the maximum voltage to neutral. A three-phase arc is shown in Figure 6.

The 60-cycle alternating-current arc passes through zero and maximum current 120 times a second. When the arc forms it rises due to the heat. This motion, together with the alternating current, causes the beautiful lace-like appearance of the arcs. The bright lines occur at maximum current.

PRACTICAL VALUE OF HIGH VOLTAGES

In addition to its purely theoretical and scientific value just discussed the production of a million volts also has a practical value. The immediate practical value is its use in testing 220-kv. apparatus with the required factors of safety. With the future in mind it is important to learn how to build transformers best suited for operating at voltages higher than those used at present. Even the so-called theoretical investigations of the present become the practical applications of the future.

PREDATORY VOLTAGES

The discussion so far has been limited to the useful type of voltage used in transmitting energy. The practical value of the research was to learn how to use these voltages without loss of energy

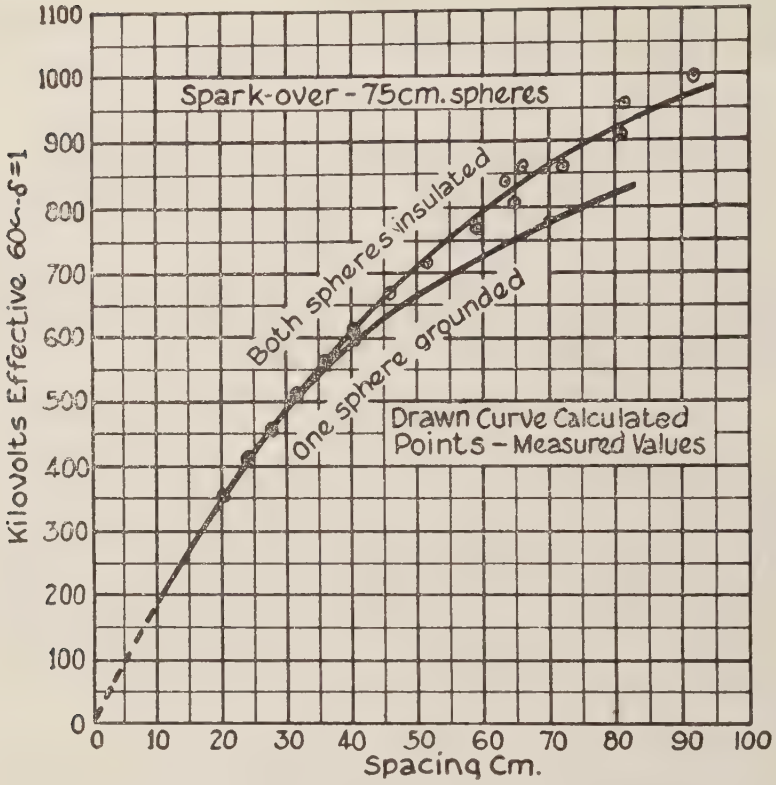

Spark-over - 75cm. spheres
Both spheres insulated
One sphere grounded
Drawn Curve Calculated
Points – Measured Values
Kilovolts Effective 60~ δ=1
Spacing Cm.
0
100
200
300
400
500
600
700
800
900
1000
1100
10
20
30
40
50
60
70
80
90

FIG. 4

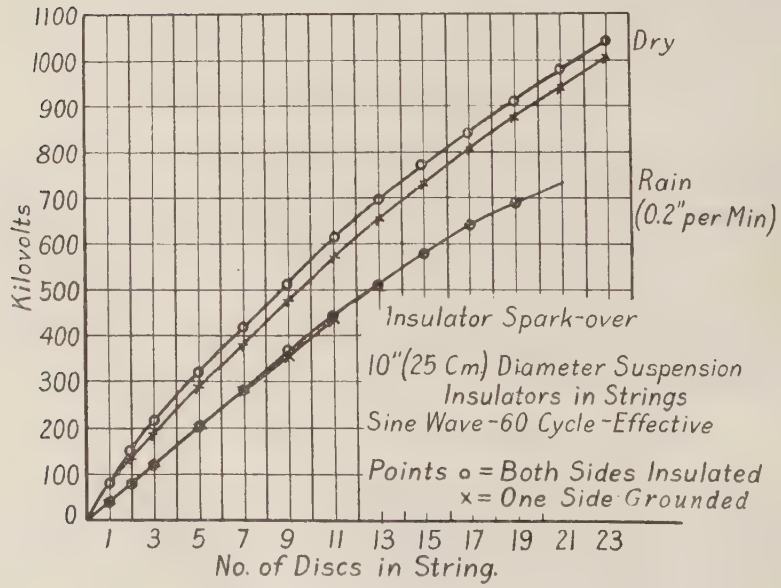

Dry
Rain
(0.2" per Min)
Insulator Spark-over
10" (25 Cm) Diameter Suspension
Insulators in Strings
Sine Wave - 60 Cycle - Effective
Points o = Both Sides Insulated
x = One Side Grounded
Kilovolts
No. of Discs in String.
0
100
200
300
400
500
600
700
800
900
1000
1100
1
3
5
7
9
11
13
15
17
19
21
23

FIG. 5

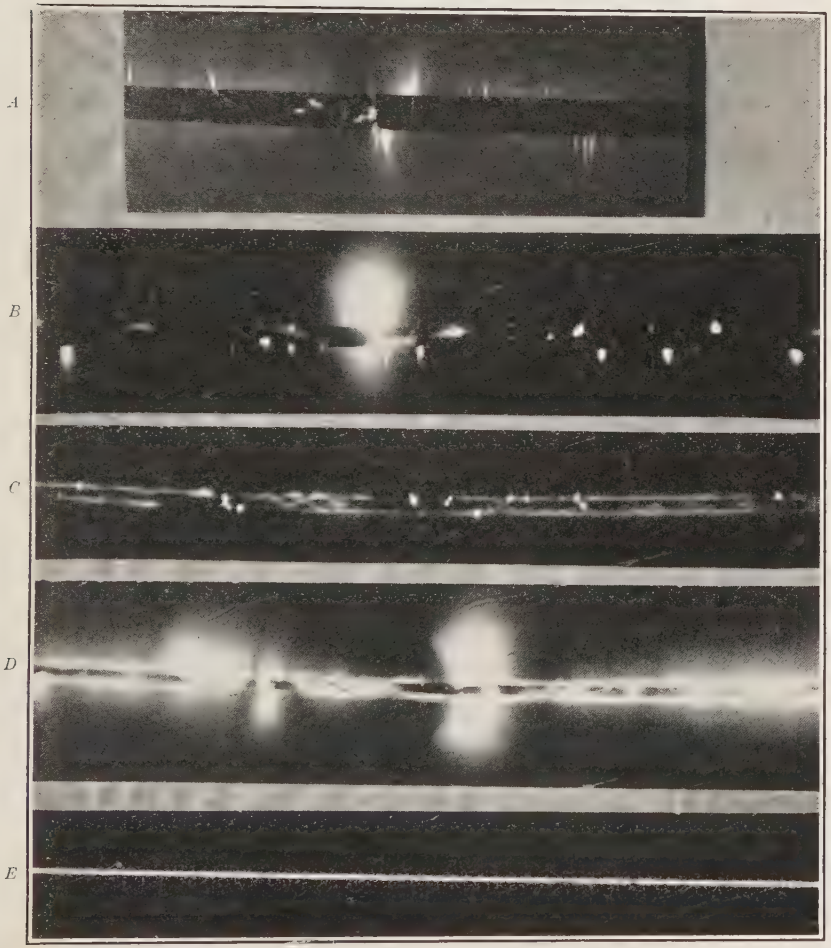


FIG. 1.—APPEARANCE OF CORONA ON CONDUCTORS AT SUPERVOLTAGES UNDER DIFFERENT CONDITIONS

A, 900 kv.; 3.5-inch tube; 144-inch spacing. *B*, 800 kv.; 1.75-inch tube; 144-inch spacing. *C*, 500 kv.; 1-inch tube; 72-inch spacing. *D*, 780 kv.; 1-inch tube; 108-inch spacing. *E*, 800 kv.; 0.040-inch tube; 144-inch spacing.

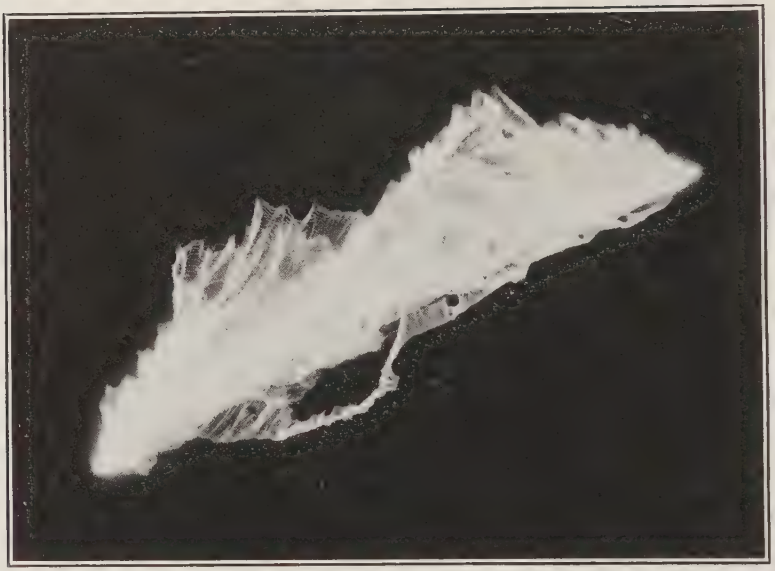


FIG. 3.—PHOTOGRAPH OF 1,500,000 VOLTS EFFECTIVE, OR 2,100,000 VOLTS MAXIMUM, SINGLE-PHASE ARC BETWEEN POINTS. DISTANCE=14 FEET. 60 CYCLES

FIG. 6.—THREE-PHASE SPARK-OVER NEEDLES AT ONE MILLION VOLTS, 60 CYCLES, SINE WAVE, EFFECTIVE. NEEDLES ARRANGED IN AN EQUILATERAL TRIANGLE APPROXIMATELY 9½ FEET ON SIDE

Photo taken at right angles to plane of needles

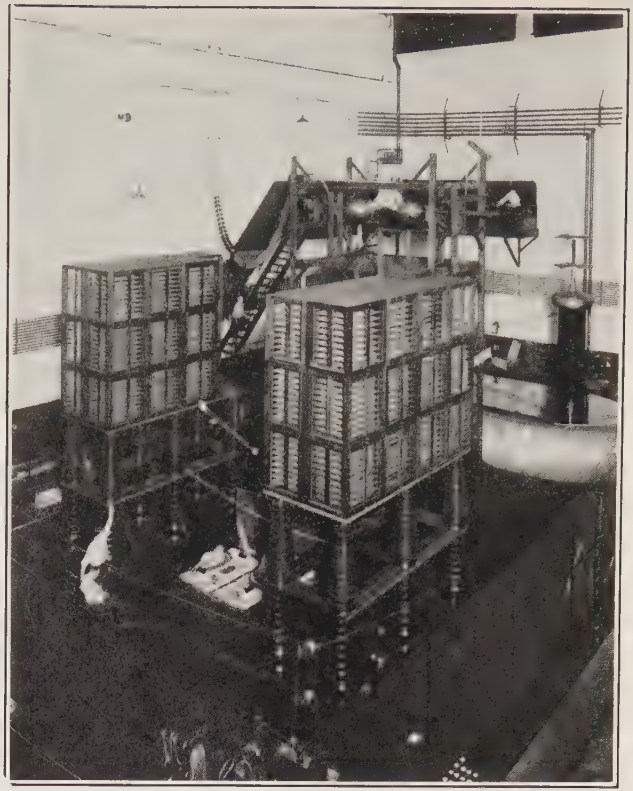


FIG. 7.—LIGHTNING GENERATOR] USED TO PRODUCE ARTIFICAL LIGHTNING

FIG. 8.—WOOD SPLIT BY ARTIFICIAL LIGHTNING

FIG. 9.—METAL "PUNCTURED" BY LIGHTNING

FIG. 10.—SINGLE 1,500,000-VOLT LIGHTNING STROKE BETWEEN POINTS

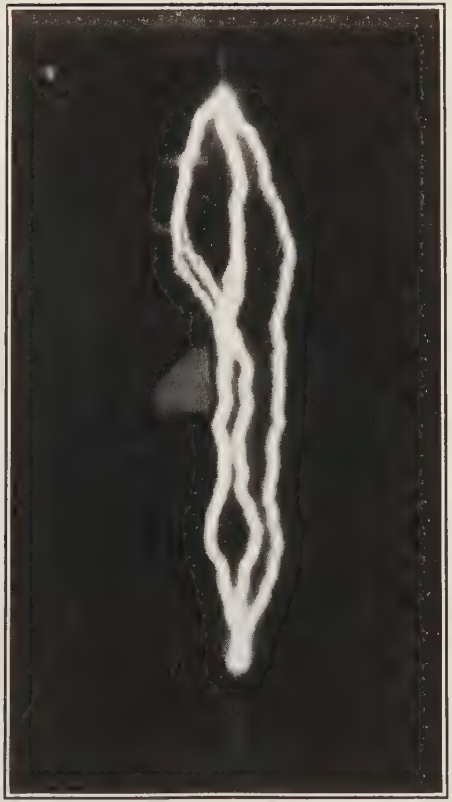


FIG. 11.—THREE 1,500,000-VOLT LIGHTNING STROKES BETWEEN POINTS. NOTE THAT SUCCESSIVE STROKES DO NOT FOLLOW THE SAME PATH

FIG. 12.—LIGHTNING DISCHARGE BETWEEN SPHERES. NOTE THICKNESS OF DISCHARGE

into the air and to prevent breakdown by spark-over. In addition it is necessary to learn how to prevent destruction by certain predatory voltages such as lightning.

IV. Lightning

A lightning stroke is generally thought of as a local but severe high-voltage discharge from some cloud. As a matter of fact, the electric energy that manifests itself in the flash is, in the moment previous to the flash, stored in the surrounding air for a considerable distance. The thunder cloud acts as one plate of a huge condenser, the earth as the other, while the intervening air is the insulation. When the voltage between earth and cloud becomes high enough, this insulation breaks down and the energy is dissipated in the short-circuit or lightning flash.

The electrical energy is changed into heat, light, sound, and chemical energy. The light is seen in the flash, while the sound is heard as thunder. Thunder is caused by air waves set up by the explosive nature of the discharge.

The chemical effects of the lightning stroke are often detected by our senses in the odor of ozone that is frequently noticeable after a storm. The chemical changes occur in the path of the discharge. The two main gases in the air are nitrogen and oxygen. Each molecule of oxygen is normally made up of two atoms. The electric field tears these apart. Some of these single atoms recombine in groups of three. Oxygen with a molcule made up in this way is called ozone. It is very active chemically because the extra atom is easily detached. The nitrogen of the air is also made to combine with the oxygen, producing nitrous oxide and, in the presence of vapor, nitric acid. Along the discharge path are untold numbers of electrons and ions—chunks of electricity moving at enormous velocities.

The voltage between cloud and ground previous to the discharge causes voltage between different parts of the atmosphere. Right under the cloud the voltage gradient or the voltage difference per foot of air measured in a vertical direction may be very high. In fact, a certain percentage of the lightning voltage exists between earth and any point above.

Lightning, the disorderly, predatory form of electricity, is dangerous, not because of its enormous energy but because of its enormous power and "flighty" habits. The distinction between energy and power is that energy is measured in kilowatt-seconds or kilowatt-hours, while power is measured in kilowatts. Kilowatts measure the rate at which work is being done. If energy is dissipated in a very short time the power is large and the result an explosion.

When lightning strikes an object great damage is generally done. However, it is not necessary for lightning to actually strike an object to cause damage. A discharge to earth may cause sparks in distant oil tanks or powder mazagines or destructive voltages on transmission lines. Voltages that occur by this "wireless" action are said to be induced.

LIGHTNING RESEARCH

A study of lightning is of scientific importance because there is manifest in the flash the dynamic effect of the electrons and ions, the elemental bricks of which it is believed that all matter is made; it is of engineering importance because an exact knowledge of the characteristics of lightning will make it possible to protect life, buildings, powder magazines, oil tanks, and transmission lines against it. The ideal method of making such a study is by observations of natural lightning in the field and researches with artificial lightning in the laboratory. Such a combined study was made in the laboratory and in the mountains of Colorado.

TWO MILLION-VOLT LIGHTNING GENERATOR

The artificial lightning was produced by a lightning generator which supplies 2,000,000 volts above ground, higher than most voltages induced on transmission lines. (See fig. 7.) The discharge from the lightning generator produces a loud, sharp explosive report, and the power is of the order of millions of kilowatts for a few millionths of a second. Currents as high as 10,000 amperes have been obtained. The voltages increase at the rate of millions of volts per second. In common with natural lightning, artificial lightning has interesting characteristics.

The large, wooden posts shown in Figure 8 were split by a 1,500,000-volt discharge. Longitudinally through the center of the stick is a hole of less than one thirty-secondth inch (0.8 mm.) in diameter. The wood around this hole has a "fuzzy" appearance, but does not appear burned. Immediately after being blown apart the wood has an odor of the gases of destructive distillation. Apparently these gases are formed suddenly by the discharge, and produce such high pressures that the wood is blown apart with great violence.

Even metal may be "punctured," as shown in Figure 9. In this case the metal formed a coating on a glass plate. The lightning discharge punctured the plate to the metal. The holes were apparently caused by the sudden formation of gases between the metal and the glass. A discharge striking through water disrupts it in much the same manner as oil is disrupted at 60-cycle voltages.

When lightning strikes the earth at some sandy spot its path is often defined by a glasslike tube. This tube, which may have branches like a tree, is, in fact, sand fused into "glass" by the lightning current. Such tubes are called "fulgurites," and can be produced by artificial lightning.

Because of the transient and explosive nature of lightning some quite unexpected phenomena frequently happen. Data will now be given on typical types of gaps, the needle gap representing the nonuniform field type, the sphere gap the uniform field, and the insulator representing the surface discharge.

Figures 10, 11, and 12 give characteristic sparks.

The lightning generator consists of high-capacity condensers just as in the case of the clouds, only the insulation is glass instead of air and it is relatively more compact.[3] As in the case of the cloud lightning, the electricity is stored at a relatively slow rate and discharged at an enormously rapid rate in a few millionths of a second.

The lightning generator has been of considerable help in gaining a knowledge of natural lightning. In fact, it has afforded a means of estimating the voltage of a real lightning stroke. The means was very simple and will be cited as an example of the general method of the research, which was to observe natural lightning and then observe artificial lightning on models built to scale in the laboratory. Actually, the function of the model is to solve electrostatic problems that are difficult to calculate.

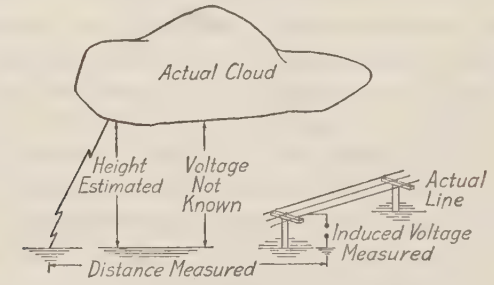
THE VOLTAGE AND ENERGY OF NATURAL LIGHTNING

It was shown in the experiments at the very high voltages that approximately 150,000 volts maximum are required for every foot of spark. While this rule was found to apply up to the very highest laboratory voltage of about 3,000,000 maximum, it in itself gave no assurance that it would apply indefinitely, so that the voltage of lightning could be found by multiplying the length of the flash by the factor. However, an experiment which seems to offer an almost direct means of measuring lightning voltages will be described. When a lightning flash occurs within a certain distance of a transmission line, a certain percentage of the voltage of the bolt is induced on the line. The voltage of the bolt can not be measured, but its distance from the line and height of cloud can be estimated. The actual voltage induced on the line can be measured by gaps or estimated from insulator flash-overs. The author has measured lightning voltages on transmission lines in Colorado as high as

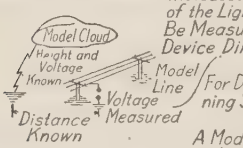
[3] A full technical description of the lightning generator will be found in the papers referred to in Note 1.

500,000; insulator flash-overs by lightning have occasionally indicated voltages as high as 1,500,000 or more.

A model was made to scale representing cloud and transmission line for a certain observed condition. By means of the lightning generator it was found that when a flash occurred from this model cloud 1 per cent of its voltage was induced on the model line. But it is known by observation that the voltage induced on an actual line under similar conditions is sometimes of the order of 1,000,000. If this is 1 per cent of the voltage of an actual lightning flash, the voltage of the flash must be 100,000,000 volts (fig. 13). This gives



On an Actual Line the Voltage Induced by a Lightning Stroke to Earth may be measured. It is also possible to determine the Distances Indicated. Because of its Magnitude the Voltage of the Lightning Stroke, However, cannot Be Measured by Putting a Voltage Measuring Device Directly Between Cloud and Earth.



For Determining the Voltage of the Actual Lightning Stroke, the Following Method is Used.

A Model Line and Cloud to Scale is Constructed in the Laboratory. By Charging the Model Cloud with the Lightning Generator, The Cloud Voltage is Known. The Voltage Induced on the Line May be Measured and Expressed as a Ratio or in Per cent of the Cloud Voltage. Knowing this Ratio and the Voltage Induced on the Actual Line, the Voltage of the Actual Lightning Stroke Can be Readily Calculated. For Heavy Strokes Under Certain Conditions the Voltage of the Actual Lightning Stroke May be of the Order of 100,000,000 Volts.

FIG. 13.—Method of measuring the voltage of an actual lightning stroke

a voltage of 100,000 per foot of spark (330 kv./m.), which, considering the possible error, indicates that the needle gap-spark curve may hold even at these extreme voltages. In fact, a value somewhat lower than the 150,000 volts per foot (495 kv./m.) of the laboratory would be expected, since the flash starts at the low-air density of the high altitudes. Time required to discharge would also indicate a reduced gradient. It has been the opinion of many observers that the voltage of lightning is relatively low or that the flash, once started, would extend great distances at low voltages by some progressive action. Progressive action is readily understood

where the spark takes place over a series of clouds by a multigap action and can, in fact, be shown in the laboratory. When the flash is from cloud to ground or from one cloud to another through clear air, as is usual with lightning, it is not clear how progressive action can occur. While the field produced by the charge is fairly uniform, it is probable that at the instant before spark-over a needlelike streamer forms and breakdown then corresponds to the needle-gap distance. Needle-gap spark-over requires less than 20 per cent of the 30 kv./cm. required for uniform field. The sparking distance should usually correspond to a continuous voltage, because there is generally no large transient until after the spark starts.

It thus appears, by approximately direct measurement, that the order of voltage of a severe lightning stroke to ground may be

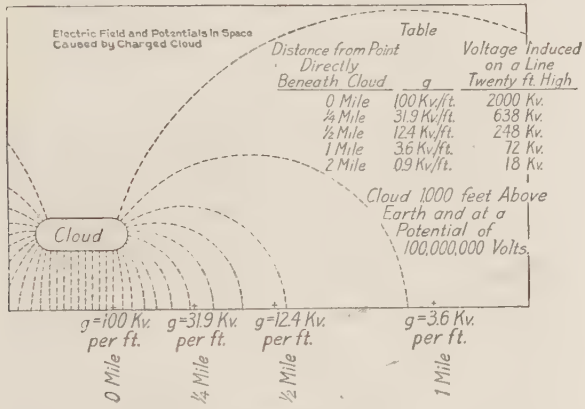

Electric Field and Potentials in Space Caused by Charged Cloud
Table
Distance from Point Directly Beneath Cloud
g
Voltage Induced on a Line Twenty ft. High
0 Mile 100 Kv./ft. 2000 Kv.
¼ Mile 31.9 Kv./ft. 638 Kv.
½ Mile 12.4 Kv./ft. 248 Kv.
1 Mile 3.6 Kv./ft. 72 Kv.
2 Mile 0.9 Kv./ft. 18 Kv.
Cloud 1000 feet Above Earth and at a Potential of 100,000,000 Volts.
Cloud
g=100 Kv. per ft.
g=31.9 Kv. per ft.
g=12.4 Kv. per ft.
g=3.6 Kv. per ft.
0 Mile
¼ Mile
½ Mile
1 Mile

Fig. 14

about 100,000,000. This is about one million times the voltage of the ordinary lighting circuit or one thousand times the voltage of a very high voltage transmission line. The lightning voltage during a storm will, of course, vary over a very wide range, sometimes much higher but generally lower than the value above. It has been observed that during a severe thunderstorm there may be many induced strokes at very low voltages, a less number of moderate voltages, and so on to very few at the extreme voltages.

It will be noted that the above conditions require a gradient of 100 kv./ft. (330 kv./m.) in the most dense part of the electric field where the flash occurs and a gradient of less than a third of this a short distance away. See Figure 14, where the gradients are given for points near the surface of the earth.

It is estimated from the voltage and the size and height of the clouds that the current is of the order of 80,000 amperes and the

energy 13,500 kilowatt-seconds or 3.8 kilowatt-hours. This energy is sufficient to operate an automobile about 5 miles or an electric toaster for a day. Since this energy is dissipated in a very short time, the power may be several thousand million kilowatts or horsepower. The effect is thus explosive and destructive.

The discharge of the cloud is probably generally nonoscillatory and takes place in the manner shown in Figure 15. A convenient measure of time is the microsecond or millionth of a second. The

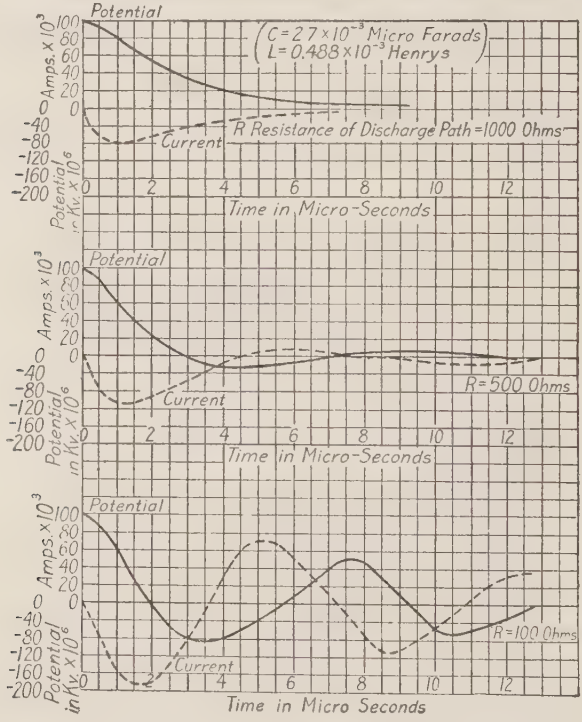

Potential
Amps. x 10³
Potential in Kv. x 10⁶
C = 2.7 × 10⁻³ Micro Farads
L = 0.488 × 10⁻³ Henrys
R Resistance of Discharge Path = 1000 Ohms
Current
Time in Micro-Seconds
R = 500 Ohms
R = 100 Ohms
Time in Micro Seconds

FIG. 15.—Transients for "cloud" discharge to earth

time of discharge may be very much longer if the resistance of the path is higher.

It may be of interest to point out that the voltage of the lightning generator is about 2 per cent and the power about 0.02 per cent of natural lightning. This practically corresponds to the lightning energy that appears on transmission lines.

LIGHTNING ON TRANSMISSION LINES

Most lightning disturbances on transmission lines occur by electrostatic induction and not by direct stroke. A charged cloud causes an electrostatic field to earth. Part of the field will terminate on

a transmission line within its area. The line is said to have a "bound charge." If the voltage between earth and cloud becomes high enough, a lightning flash will occur. Although this flash may be a mile away from the line, the charge on the line is released and the insulated line increases from earth potential to some value above with polarity opposite to that of the cloud. An insulated line can be at earth potential just previous to the discharge because of the effect of the long part of the line not under the cloud, leakage over insulators, or through grounded neutral. A charge of the same sign as the cloud leaks away leaving a bound charge on the line with sign opposite to that of the cloud. The line remains at

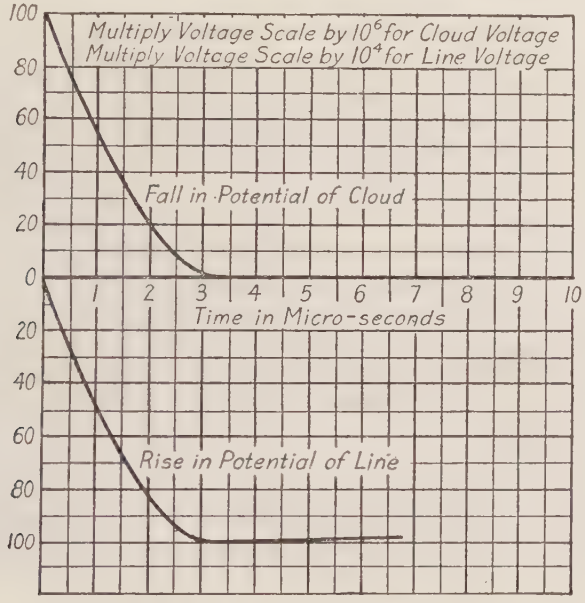


FIG. 16.—Transients for cloud discharge to earth

earth potential until the cloud discharges. The effect is then of a voltage suddenly applied between line and ground. The voltage of the line becomes maximum when the cloud voltage becomes zero. The manner in which the voltage increases on the line with decrease in voltage on the cloud is shown in Figure 16. The field that extended between line and cloud now extends between line and ground. The voltage wave travels over the line at the velocity of light. If the line insulators are strong enough or have a high enough impulse ratio, the impulse may travel to the power house to break down apparatus or to be harmlessly discharged to ground over the arrester, if it has low reactance and low impulse ratio. As this lightning wave travels over the line it becomes gradually dissipated

by losses. The voltage that the line assumes at the instant of a sudden discharge is that of the equipotential surface at the point in which the line is located. This is approximately the gradient in kilovolts per foot times the height in feet. This is a certain percentage of the voltage of the lightning bolt. In studies in Colorado, as already stated, the author has actually measured induced lightning voltages on transmission lines as high as 500,000 volts. Insulator flash-overs have occurred that indicate induced voltages as high as 1,500,000 volts, although the greater percentage of voltages induced on transmission lines are very much lower than this. These figures, as already shown, afford a means of estimating the voltage of a lightning flash.

THE MAXIMUM VOLTAGE ON TRANSMISSION LINES

From the above it is apparent that the maximum lightning voltage that can appear on a transmission line under given conditions depends directly upon the height of the line. The maximum voltage that can appear on any line is equal to the maximum possible gradient of 100 kilovolts per foot or 100,000 volts per foot times the height of the line in feet. This extreme condition seldom occurs because it requires the discharge to take place at a very rapid rate in the immediate vicinity of the line, practically a direct stroke. The chances of this condition are remote because when the storm center is only a quarter of a mile away the gradient is reduced to one-third. It may also be reduced by a slow discharging cloud permitting a considerable dispersal of the charge along the line. Apparent gradients of 20,000 to 30,000 volts per foot are fairly common on actual lines. The tabulation in Figure 14 shows the induced lightning voltages on a 20-foot transmission line at different distances from the rapidly discharged cloud.

Practically, this shows that a high transmission line is undesirable from the lightning standpoint. It also affords a means of determining the maximum lightning voltage that can appear on a transmission line.

The maximum voltage induced on the line is 1 or 2 per cent of the cloud voltage. The energy is of the order of 1,350 watt-seconds. The character of the discharge is generally impulsive and reaches its maximum in a few microseconds. In fact, it corresponds closely to the discharge from the lightning generator in voltage, energy, and duration.

TRAVEL OF LIGHTNING ON TRANSMISSION LINES

A lightning disturbance travels over the line at the velocity of light, and is dissipated to a considerable extent by losses; it may

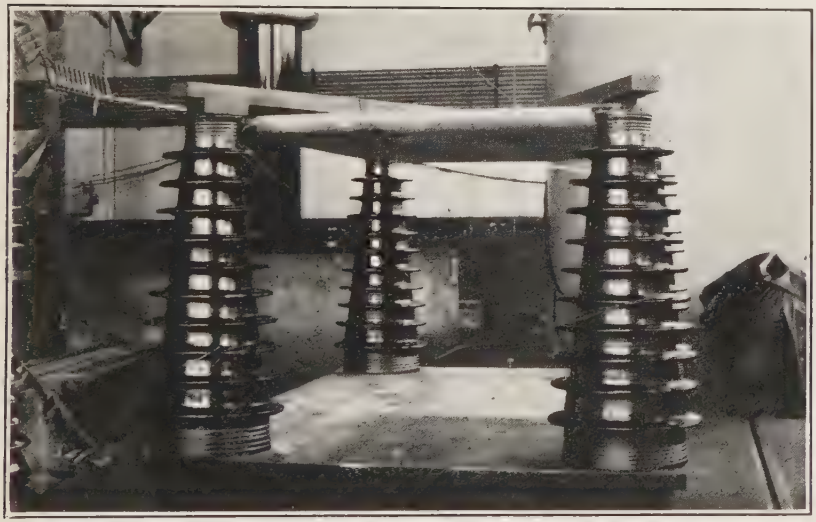


FIG. 18.—STUDY OF THE VOLTAGES INDUCED UPON TRANSMISSION LINES

Photograph shows overhead cloud and a section to scale of one of the lines studied during the investigation

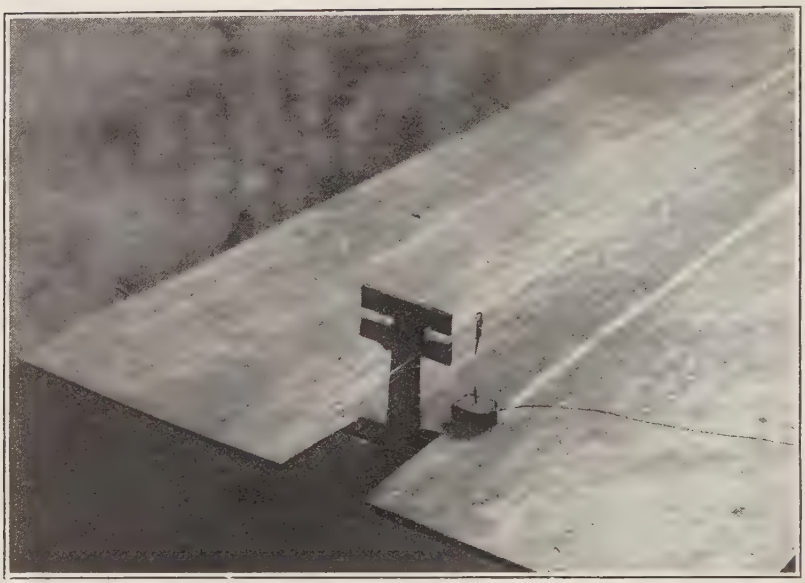


FIG. 19.—SHORT SECTION OF A THREE-PHASE LINE WITH OVERHEAD GROUND WIRE UPON WHICH A STUDY WAS MADE OF INDUCED VOLTAGES BY LIGHTNING

Photograph shows one of the "towers" and one of the spark-gaps used to measure voltage at this point

FIG. 20.—LIGHTNING STROKES HITTING THE OVERHEAD GROUND WIRE OF A TRANSMISSION LINE DURING STUDY OF LIGHTNING VOLTAGES INDUCED ON A THREE-PHASE LINE DURING A STORM

double in value when it strikes the end of the line where it starts back. If the voltage is high enough it may break down insulators or discharge over an arrester. If no break occurs it is eventually dissipated by losses. The change in shape and voltage of lightning waves traveling along transmission lines at 186,000 miles per second has been measured in the laboratory.

The strength of the insulation of lines operating at various voltages was determined by measurements with artificial lightning. By comparing the insulation strength with the maximum lightning voltage the ability to withstand lightning was determined.

THE GROUND WIRE

When a grounded wire is placed near and parallel to the transmission wires it has a marked effect on the induced voltages. The effect of the ground wire was studied on models to scale. The diagrammatic arrangement is shown in Figure 17, while the actual models are shown in Figures 18, 19, and 20.

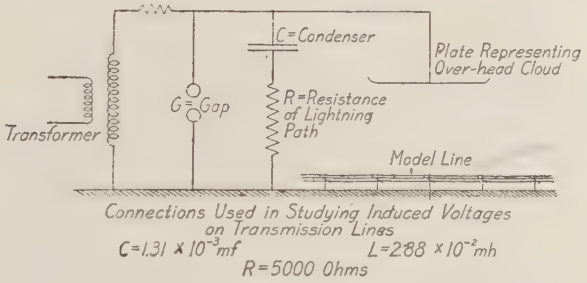


FIG. 17

The method of making the test was to measure the induced voltages on the model line with and without a ground wire. In general the single ground wire reduces the induced lightning voltage to one-half, two to one-third, and three to one-fourth. Very good connections must be made to ground. The ground wire thus offers an important practicable means of reducing lightning voltages. It is also important in case of a direct stroke, when the ground wire is struck 98 per cent of the time.

INSULATING A TRANSMISSION LINE TO WITHSTAND LIGHTNING

The investigation has shown the maximum lightning voltages that can occur on transmission lines with and without a ground wire. It is of interest to compare these voltages with the lightning insulator arc-over voltages for modern transmission lines.

The lightning spark-over voltage for insulators and the lightning breakdown voltage for insulation is always higher than for

steady voltages. In fact, this is true for all transient voltages that can occur on transmission lines. Rain lowers the arc-over voltage of insulators at 60 cycles, but does not reduce the lightning spark-over voltage. The curves of insulator spark-over voltages for transient and operating conditions are given in Figure 21.

The transient voltage curves cover the range of lightning, switching surges, and surges due to arcing grounds. The surges other than lightning are limited in value by the line voltage. Except as it is affected by the height of tower, lightning is independent of line voltage. It is the determining factor in insulation.

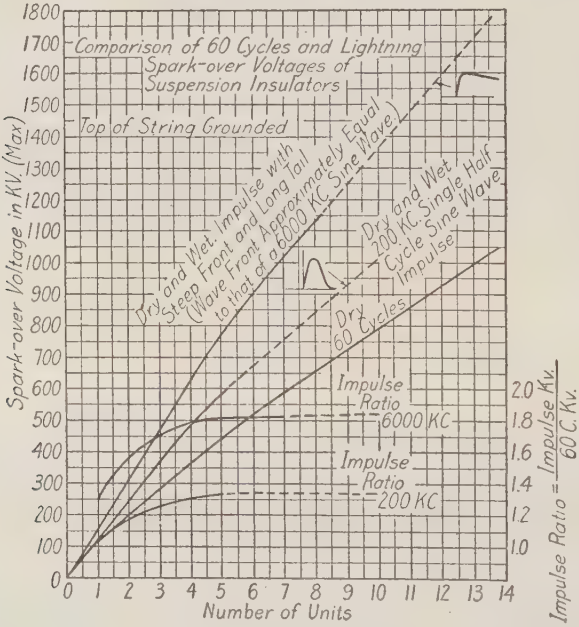


Fig. 21

The lightning flash-over voltage of insulators is plotted with operating voltage in Figure 22. On this same figure are plotted curves of the probable highest lightning voltage for lines with and without ground wires. A direct stroke on a line without a ground wire causes voltages much higher than the insulator arc-over voltage. The second curve down represents the usual highest voltage on a line without a ground wire. It happens that this same curve corresponds to the voltage by a direct stroke on a line with one ground wire. This curve crosses the insulator spark-over voltage of 220 kv. This indicates that a 220-kv. line without a ground wire is not likely to have insulator trouble from lightning except in case of direct stroke. It further indicates that a 220-kv.

line with a favorably installed ground wire is not likely to have trouble from lightning under any circumstances, unless the towers are very high. The next curve gives the usual highest voltage for a line with one ground wire. Under usual conditions, very little trouble should be expected for lines insulated for over 100-kv. operation. The lowest curve shows that three ground wires reduce the probability of lightning to still lower operating voltages. The probability of trouble with direct strokes would be reduced in proportion.

The values of voltages taken in the above curves are for the most severe storms directly over exposed lines. Such conditions might not occur during a year or several years. It is a well-established fact that during any storm there are likely to be induced many low-voltage impulses, a less number of moderate-voltage impulses, and frequently none at high voltage.

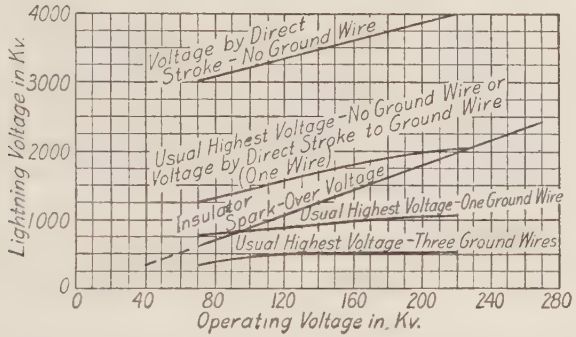


Fig. 22.—Insulator spark-over voltage compared with maximum lighting voltage for severe storms directly over the line

Lightning voltages are likely to cause high local stress in inductive apparatus such as transformers. In designing inductive apparatus to withstand lightning voltages, it is important to prevent concentration of stress. This can be done by means of shields. Like the ground wire, the action of the shield is preventative. Shields have been used on both line insulations and transformers.

LIGHTNING ARRESTERS

Preventive methods of guarding against lightning on transmission lines, such as the ground wire, shields, and extra insulation, have already been discussed. The remaining method is the lightning arrester.

The object of the arrester is to permit transient or other excess voltages to discharge to earth and to suppress the dynamic arc that follows. Since transient currents are generally high, the arrester

must have a low resistance. It must also have a low time lag, otherwise the transient voltage may rise to high values before the discharge occurs.

Figure 22 shows that the need of an arrester becomes less as the operating voltage increases.

Corona and other losses also rapidly reduce lightning voltages.

OTHER CAUSES OF TROUBLE ON TRANSMISSION LINES

Most troubles on transmission lines are caused either by lightning voltages in excess of the insulation breakdown voltage or to some form of dirt that lowers the normal breakdown voltage to such an extent that failure occurs under normal conditions.

Certain transient voltages are produced in lines during switching, etc., but these are usually quite harmless.

CORONA AND SPARK OVER OF LIGHTNING VOLTAGES

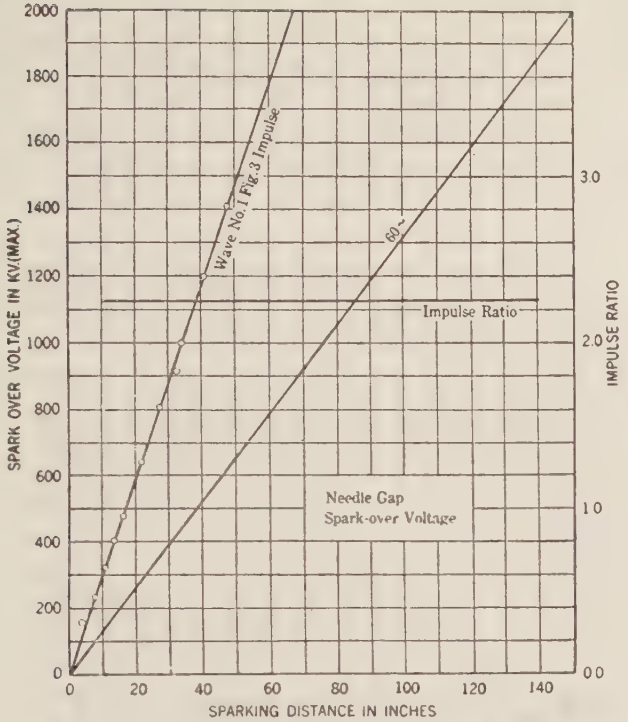
The corona and spark-over voltages due to lightning are usually quite different from the continuously applied 60-cycle or direct-current voltages. This also applies to liquid and solid insulation. The lightning voltage is a transient or impulse and in effect is applied at an extremely rapid rate. The insulation does not have time to break down when its usual breakdown voltage is reached but the break is completed at a later time when the voltage has risen to a higher value. The time lag will be discussed in more detail later.

CORONA

Lightning voltages cause corona in the same manner as continuously applied voltages. Corona produced by lightning voltages of less than a microsecond duration (millionth of a second) can be readily seen. It is also easy to tell whether the impulse is positive or negative. In general, corona produced by impulse voltages follows the same law as corona produced by continuously applied voltages. It is of interest that the eye can readily see corona produced by voltage of a microsecond duration.

SPARK-OVER OF NEEDLE GAPS

A typical discharge from the lightning generator at 1,500,000 volts between points is shown in Figure 10. The discharge has a zigzag path and characteristic side flashes of lightning. The lightning spark-over curve for needle gap is given in Figure 23. This curve shows that for the particular impulse used (fig. 24) a voltage is required approximately 2.25 times the 60-cycle voltage to spark over a given gap. The factor 2.25 is called the impulse ratio.



LIGHTNING SPARK-OVER CURVE BETWEEN POINTS

FIG. 23

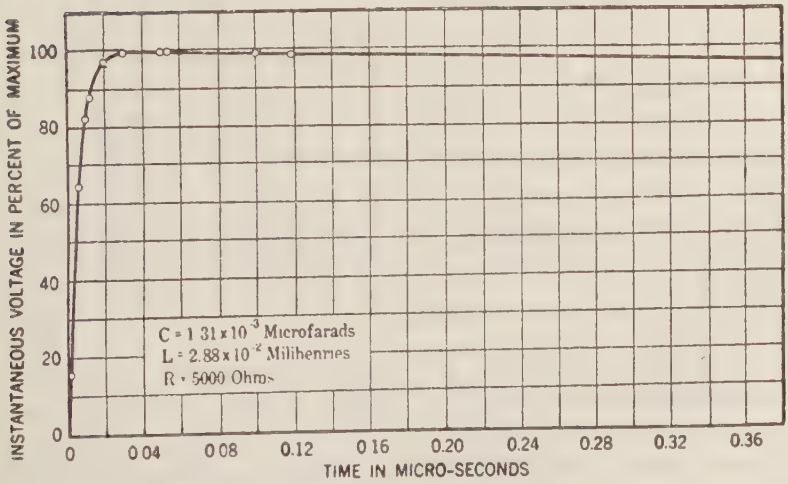


FIG. 24.—Wave shape of lightning used in the tests. Wave shape No. 1. Two million-volt impulse generators

THE SPHERE GAP

While the impulse spark-over voltage of the needle gap varies with the wave shape of the impulse and is always higher than the 60-cycle spark over, the sphere gap is very little affected, even for quite steep waves. The sphere gap thus offers a means of measuring transient voltages over a considerable range. Figure 12 shows a typical sphere gap spark, and Figure 25 shows that the spark-over

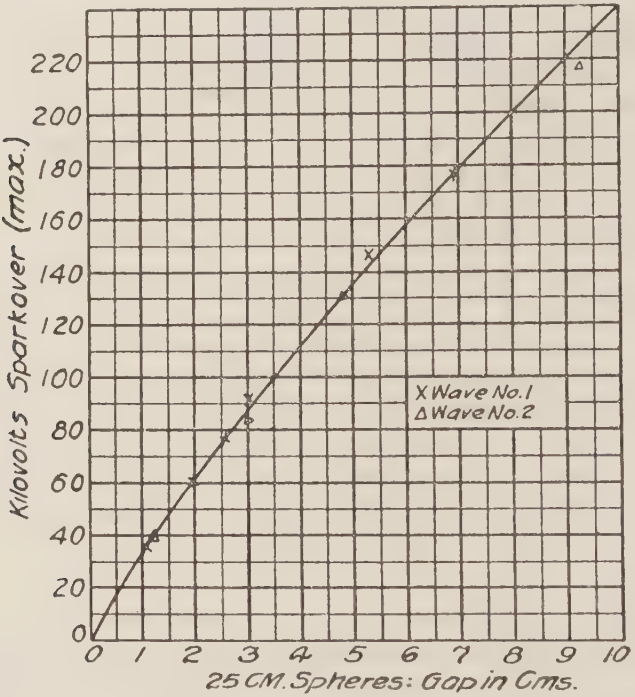


FIG. 25.—Sphere gap spark-over curves for 60 cycles and for impulse waves Nos. 1 and 2. Wave No. 1, single half sine wave impulse; wave No. 2, impulse with steep front, but with a long tail. (Drawn curve is for 60 cycles; points are for waves Nos. 1 and 2, as noted.)

voltages for a given gap do not vary over a very wide range of transients.

LINE INSULATORS

Investigation at the lower voltages showed that the wet and dry lightning spark-over voltages of insulators were equal. Tests made at the higher voltages confirm these data. Typical 60-cycle and lightning arcing characteristics for shielded and nonshielded insulator strings are shown in Figures 27 and 28. The shield consists of a metal ring at the line end of the string. It serves to distribute

the voltage evenly between the units as well as to direct the arc away from the string.

These tests are of practical importance, since lightning voltages higher than these rarely occur on operating transmission lines. The lightning spark-over voltage was found to be twice the 60-cycle spark-over voltage. The impulse ratio was increased by the shield. The wet and dry lightning flashes clear the shielded string while on the nonshielded string the flash cascades and is likely to rip off the skirts.

It will be noted that the three typical gap arrangements have different characteristics. Both the needle gap and the insulators require a lightning voltage about double the 60-cycle voltage to

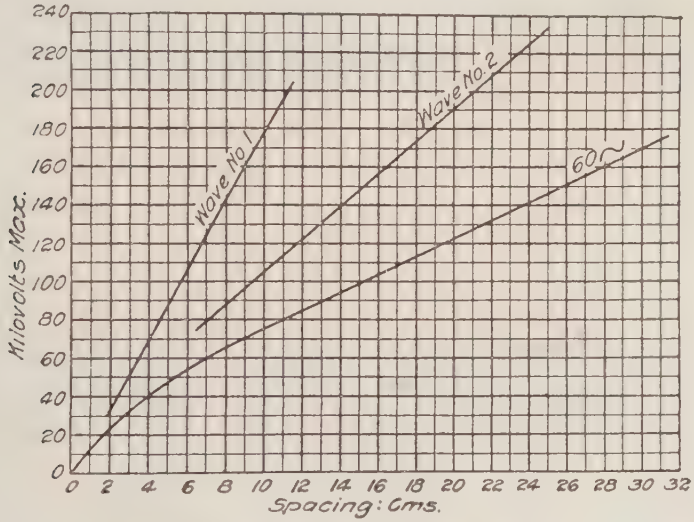


FIG. 26.—Needle-gap spark-over curves for 60 cycles and for impulse waves Nos. 1 and 2. Wave No. 1, single half sine wave impulse; wave No. 2, impulse with steep front, but with a long tail

cause spark over, while the sphere spark-over voltage is the same for 60-cycle and a wide range of impulse voltages. This characteristic is of great practical importance, since it is desirable to have an arrester gap that discharges at a low lightning voltage and to design insulators that have a high lightning spark-over voltage. The reason for this is time lag, and it seems worth while to discuss it briefly.

TIME LAG

A fixed minimum voltage is required to spark over a given gap when the time of application is not limited. Energy is necessary to rupture gaseous, liquid, and solid insulation; this introduces a time element.

Referring to Figure 29 the spark-over voltage of a given needle gap is e_1, and always practically constant if the time of application is not limited. Spark over may take place after the continuously applied voltage e_1 has been on for some time t_1. If a voltage increasing at a rapid rate, as represented by A in Figure 29, is applied, spark over will not take place when the continuously applied spark-over voltage e_1 is reached, as the time t_1 is required at this voltage. The spark will begin to form when the voltage reaches the value e_1, however. The voltage will, therefore, rise above e_1, and spark over will take place after the time t_2 has elapsed and the voltage has risen to e_2. When the voltage is applied at a more rapid rate along wave B, the spark, as before, will begin to form when voltage e_1 is reached. The voltage will continue to rise and reach some

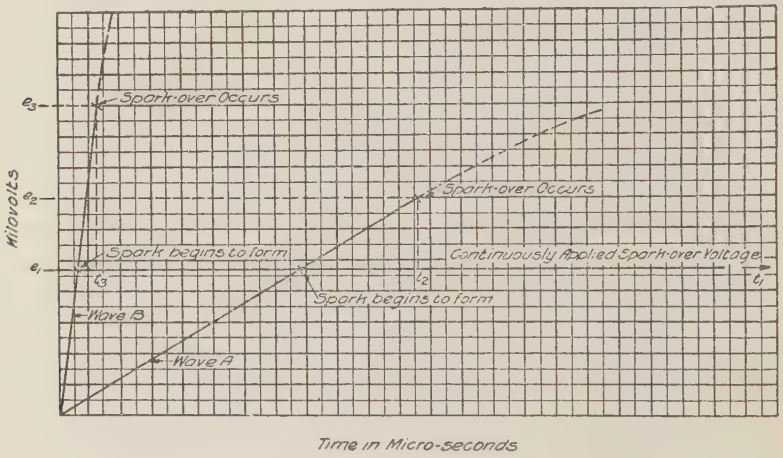
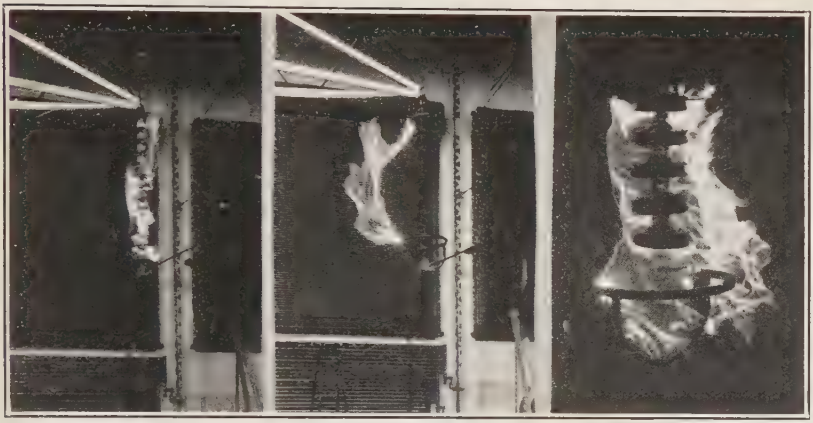


FIG. 29.—Diagrammatic illustration of why the lightning or impulse spark-over voltage is higher than the continuously applied

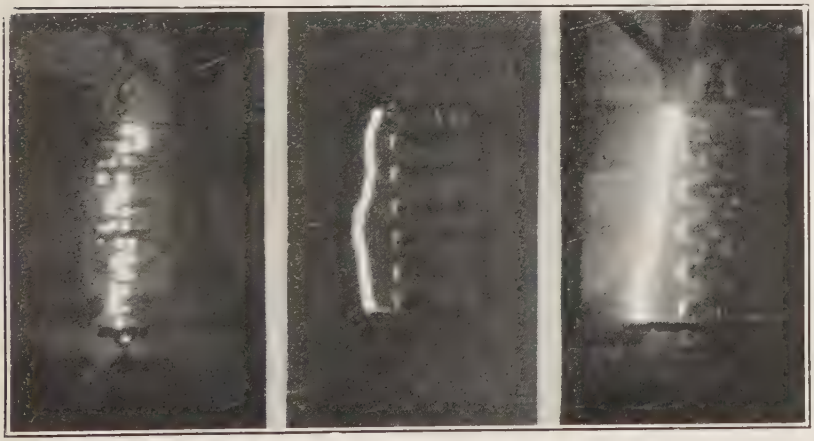
value e_3 during the time t_3 before the spark over occurs. Thus, on account of the time lag, when voltage is applied at a very rapid rate, as by an impulse, spark over does not occur when the continuously applied breakdown voltage is reached. The voltage "overshoots" this value during the time that rupture is taking place. The excess in voltage is greater, and the time lag less, the greater the rate of application. The time lag for any given gap or insulation has thus not a fixed value but depends on the wave shape of the impulse or rate of application of the voltage. In making a study of such phenomena it is necessary to use certain definite wave shapes. Figure 30 shows the impulse voltage-time characteristic for needle gaps. The impulses used in this test were single half cycles of sine waves. Note that the impulse spark-over voltage is not greatly above the continuously applied or 60-cycle voltage when the time is over 5 microseconds; that is, when the time of application is comparatively



A *B* *C*

FIG. 27.—SIXTY-CYCLE SPARK-OVER OF SUSPENSION INSULATOR STRINGS

A, Dryspark-over on a nonshielded string. Note that arc cascades badly along the entire length of string. *B*, Dry spark-over on a string shielded with the ring shield. Note that arc clears string. *C*, Wet spark-over on a string shielded with the ring shield. Arc starts through drip then immediately transfer itself clear of string



A *B* *C*

FIG. 23.—LIGHTNING SPARK-OVER OF SUSPENSION INSULATOR STRINGS

A, Dry spark-over on a nonshielded string. Note that the arc cascades badly along the entire length of string. Voltage=1,200,000 volts. *B*, Dry spark-over on a string shielded with the ring shield. Note that the arc clears the string. Voltage=1,200,000 volts. *C*, Wet spark-over on a string shielded with the ring shield. Note that arc clears the string. Voltage=1,200,000 volts. Note, also, the drip along the string and the raindrops which appear stationary in space since the light of the arc lasted less than a millionth of a second

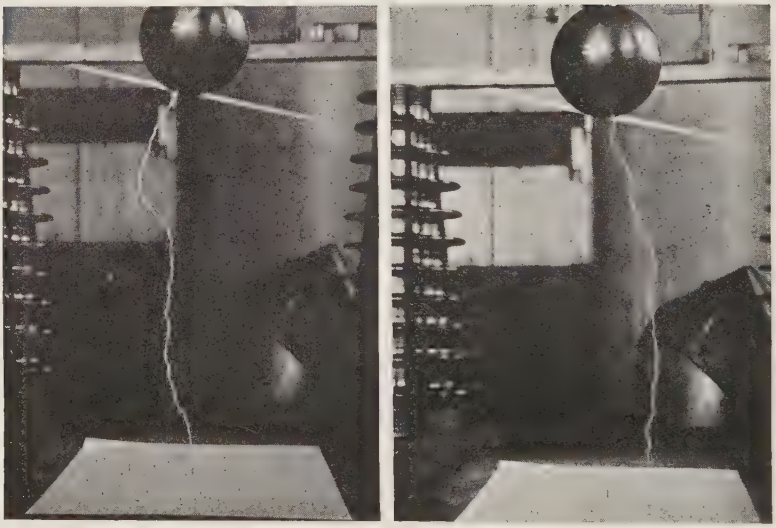


FIG. 32.—LIGHTNING DOES NOT ALWAYS HIT THE HIGHEST POINT

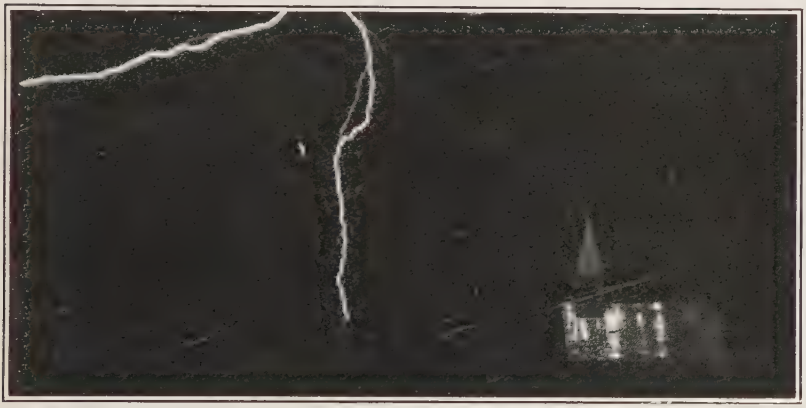


FIG. 39.—ARTIFICIAL LIGHTNING STROKE FROM THE 2,000,000-VOLT LIGHTNING GENERATOR STRIKING HOUSE AND CHURCH OF MODEL VILLAGE DURING STUDY OF LIGHTNING PROTECTION OF BUILDINGS

long there may be a considerable variation of this time without an appreciable change in the spark-over voltage. The continuously applied (60-cycle, or $d—e$, where heating does not occur) spark-over voltage is the lowest voltage at which spark over can take place.

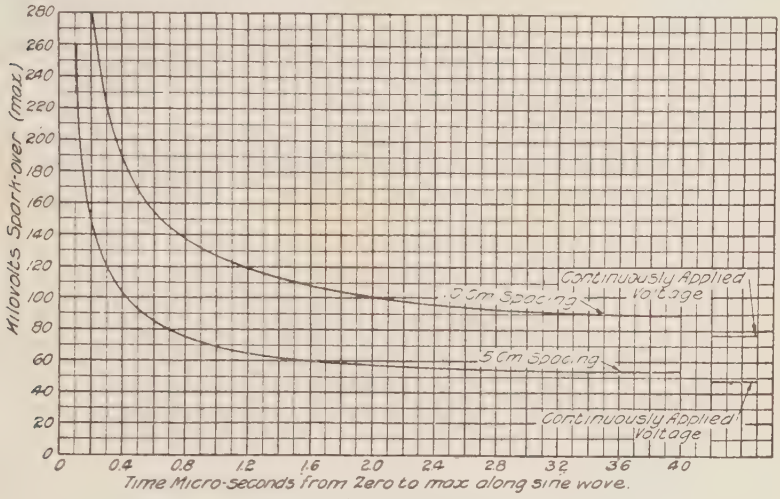
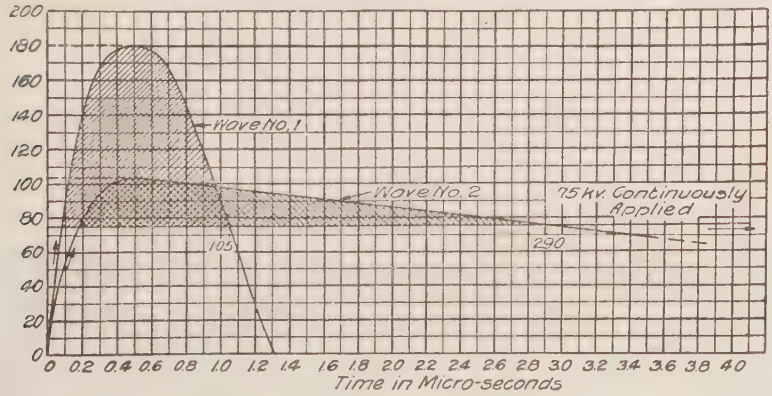

Kilovolts Spark-over (max.)
Time Micro-seconds from zero to max along sine wave.
.5 Cm Spacing
Continuously Applied Voltage
5 Cm Spacing
Continuously Applied Voltage

FIG. 30.—Time and voltage to spark over needle gaps with a sine wave impulse

Waves (1) and (2) (fig. 31) show actual wave shapes used in obtaining data given in Figures 25 and 26. Wave (1) is equivalent to a single half cycle of a sine wave; wave (2) rises to a maximum



F|7. 31.—Continuously applied and impulse voltages to just cause spark over of a 10-cm. gap between needles

at the same rate as wave (1) but has a flat top, or is of much longer duration. Of the two waves shown in Figure 31 the voltage required to spark over a given gap is higher for the one of shorter duration or for wave (1). In this figure, where actual test data are given for a 10-cm. gap between needles, spark over results at 180 kv. for

wave (1), while for wave (2) spark over results at 104 kv. The spark over at 60 cycles is 75 kv. The time that wave (1) is above the continuously applied breakdown voltage is 0.95 microseconds, wave (2), 2.70 microseconds. The impulse and continuously applied needle gap spark-over curves are given in Figure 26. An examination of Figure 26 shows that the impulse spark-over voltage of needles is always higher than the continuously applied spark-over voltage, for a 10-cm. gap is 180 kv., or 2.4 times the 60-cycle or continuously applied voltage.

The time to spark over a gap varies with the spacing and shape of the electrodes. For a given 60-cycle voltage setting the time re-

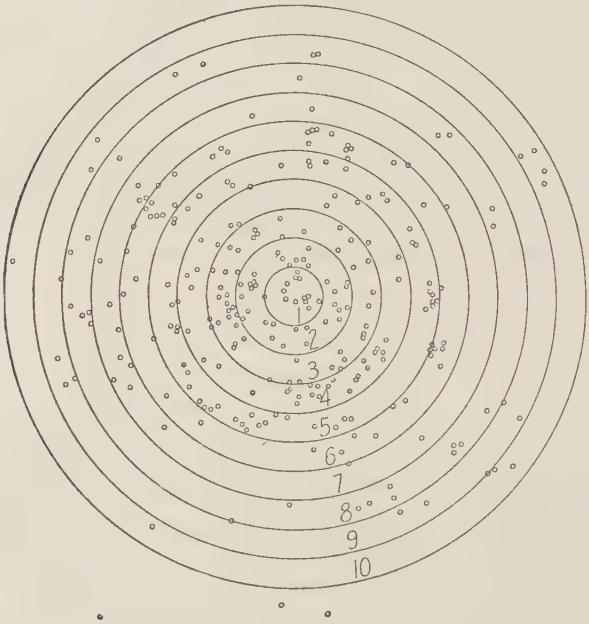


FIG. 33.—Target made by lightning. No needle

quired to form a spark is greatest for gaps between points and least for gaps between well-rounded surfaces. For spheres, the time lag is so small that discharge takes place before the impulse voltage can rise appreciably above the continuously applied or 60-cycle spark-over voltage. This is shown in Figure 25, where the drawn curve is the 60-cycle curve, while the impulse spark-over voltages for waves (1) and (2) are represented by crosses and triangles.

The needle gap requires the maximum time of any gap, as considerable air must be ionized before spark over can result. Another way of considering it is that the corona increases the capacity and places resistance in series with it as it forms. It requires time to charge a condenser through resistance.

On the other hand, spheres are very little affected because corona does not precede spark over, and the discharge is small and confined to a short path. The field is very nearly uniform, and ruptures start everywhere along the path between the electrodes at approximately the same time.

THE LIGHTNING ROD

A study was made, using models built to scale, to determine the protective value of lightning rods. In making these tests, voltages varying from 60 cycles to oscillations and impulses were used. The "clouds" were also varied from a point to a large flat plane.

FIG. 34.—Target made by lightning. ½-inch needle

It seems that all possible conditions were covered by this range, and since the general behavior of the discharges was the same in all cases, it is believed the results apply to actual lightning discharges.

In making the tests the rod was placed in the center of a large piece of drawing paper on a flat plane. Unless otherwise stated, the plane was of metal. The cloud was placed above the rod. The tests show that lightning from a cloud overhead does not always strike the highest object. The discharges either took place to the rod or to the plane. When the discharge hit the paper a small hole was made. A record was thus obtained of the distribution of the discharges. When the cloud was a plane, a small point was placed at its center to represent the storm center. The apparatus is shown in Figure 32, while sample charts are shown in Figures 33 and 34.

AREA PROTECTED BY A ROD

The general character of the division of hits between a rod and the surrounding ground is shown in Figure 35. In this specific

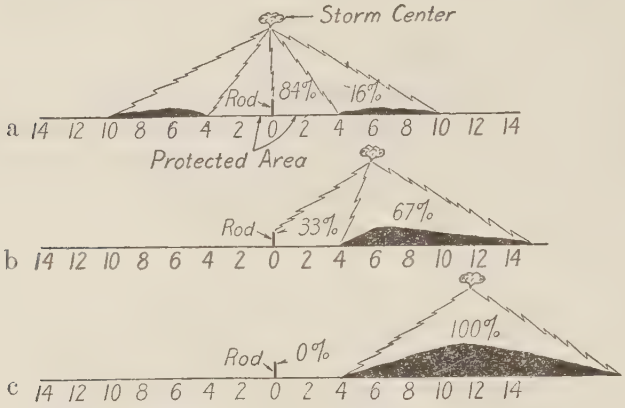


FIG. 35.—Protected area and distribution of hits between rod and ground for different positions of storm center

example, taken for illustration, the rod is located on a conducting plane and is 1.85 per cent of the cloud height. In (a), Figure 35,

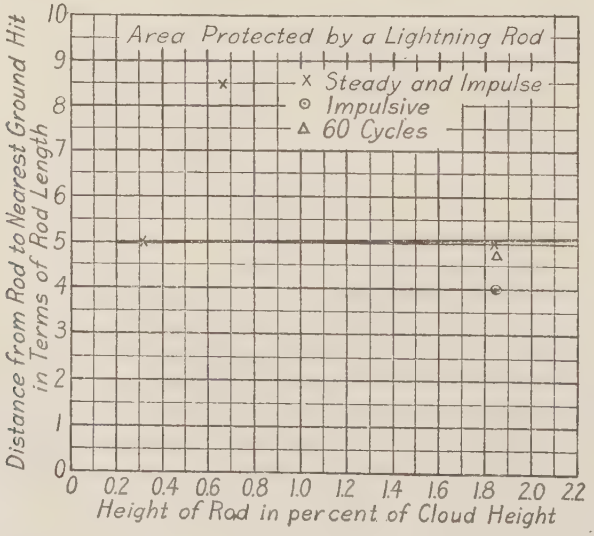

Area Protected by a Lightning Rod
Steady and Impulse
Impulsive
60 Cycles
Distance from Rod to Nearest Ground Hit in Terms of Rod Length
0 1 2 3 4 5 6 7 8 9 10
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
Height of Rod in per cent of Cloud Height

FIG. 36

the storm center is located directly above the rod. Under this condition 84 per cent of the strokes hit the rod, while 16 per cent hit the ground approximately as shown in the shaded portion.

There are no ground hits in an area between the rod and four rod lengths away. This protected area is well illustrated in Figure 34 and seems to hold for all conditions as shown in Figure 36.

The division of hits as the storm center moves away from the rod is illustrated in (b) and (c) Figure 35. Eventually, a distance is reached when the rod is no longer struck. This occurs for this particular rod when the projection of the storm center is about 30 per cent of the cloud height away from the rod. There are no ground hits closer to the rod than four times its height for the extremes given in Figure 35.

DIVISION OF HITS BETWEEN ROD AND GROUND FOR DIFFERENT HEIGHTS OF ROD

The division of hits between a lightning rod and ground, when the rod is located directly under the storm center, is shown in Figure

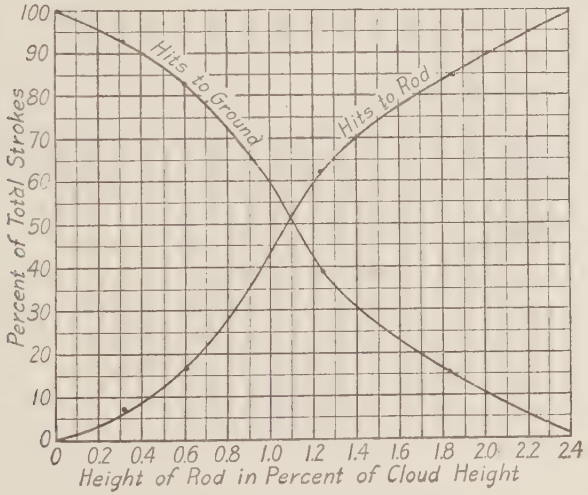


FIG. 37.—Division of hits between rod and ground for different heights of rod

37. When the rod has zero length, 100 per cent of the hits, of course, must strike the ground. When the height of the rod is 1.1 per cent of the cloud height, the division of hits is equal, while all of the strokes go to the rod when it is about 2.5 per cent of the cloud height. Over this range the ground was never hit nearer to the rod than four times its height.

HITS PER UNIT AREA UNDER A STORM CLOUD

Figure 38 shows the ground hits per unit area at various distances from rods of different heights. The rods are directly under the storm center. With rods of zero height 1 per cent of the hits

per unit area occur directly under the storm center. The number of hits per unit area decreases rapidly until there are no hits at about 25 per cent of the cloud height away from the center. With a rod 0.6 per cent of the cloud height, 16 per cent of the strokes strike the rod (fig. 37). There is a protected area where no ground hits occur (fig. 38). The maximum ground hits per unit area, 0.7 per cent, occur at about 8 per cent of the cloud height from the center. No ground hits occur at 25 per cent of cloud height from the center.

CHANCE OF BEING STRUCK

The above data offer a means of estimating the relative chance of objects of different heights being struck during a thunderstorm

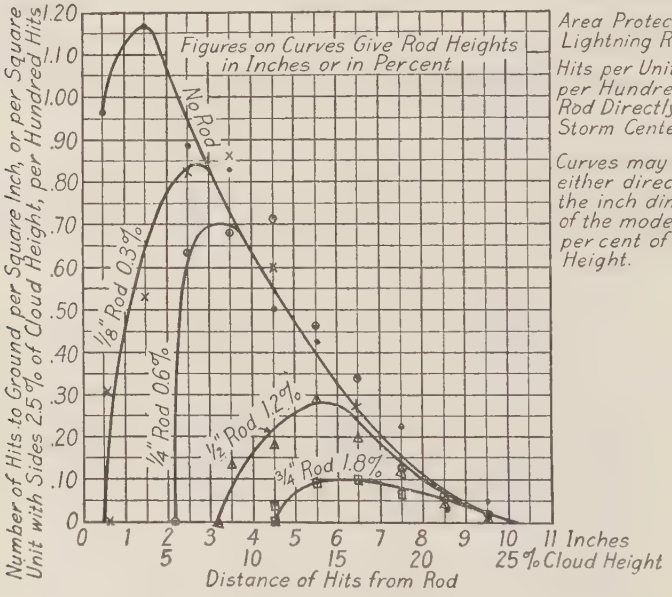

Number of Hits to Ground per Square Inch, or per Square Unit with Sides 2.5% of Cloud Height, per Hundred Hits
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
Figures on Curves Give Rod Heights in Inches or in Percent
No Rod
⅛" Rod 0.3%
¼" Rod 0.6%
½" Rod 1.2%
¾" Rod 1.8%
Area Protected by Lightning Rods.
Hits per Unit Area per Hundred Strokes. Rod Directly Under Storm Center
Curves may be read either directly in the inch dimensions of the model or in per cent of Cloud Height.
0 1 2 3 4 5 6 7 8 9 10 11 Inches
5 10 15 20 25% Cloud Height
Distance of Hits from Rod

FIG. 38

when the cloud is overhead and of sufficient voltage to discharge to earth.

Assume a cloud 1,000 feet high. A 6-foot man on a plane directly under the storm center (from fig. 37) would be hit 15 times out of every 100 strokes, while a 25-foot building would be hit every time. A man flat on the ground (from fig. 38) would be struck about once for every hundred strokes. An 18.5 foot building directly under the storm center would be struck 84 times out of 100 hits. However, with the storm center moved only 296 feet this building would not be struck.

These data are useful in determining the best methods of protection, because they tell what will happen when conditions are such that discharges can take place to the house or rod under consideration. In other words, the data give the chance of an object being struck when it is directly under a cloud at sufficient potential to cause a discharge. To determine the chance of any object being struck during a year, it is also necessary to know the chance of a cloud of sufficiently high potential passing over the object. It is apparent that this chance is usually quite small even when the object is located on a plane. When mountains, hills, and trees are added the chance becomes still less.

PROTECTION OF BUILDING

The lightning rod is of real value in preventing or limiting damage when a building is struck. Whether or not it increases the chance of being struck depends upon circumstances. It is rather doubtful if it often does, as a chimney, grounded gutter, or water pipe may be sufficiently conducting to determine the direction of the stroke.

In deciding upon a lightning rod the economic factor or the cost of protection must be considered in connection with the probability of being struck. It seems that the best results can be obtained with plain inconspicuous rods. Ornate rods or rods with special points appear to have no advantage. A grounded metal roof would seem almost ideal protection. Rods should be installed so that side flashes are not likely to occur to conducting objects inside or outside of the building. When a building is in an exposed position and storms frequently pass over it, a more elaborate outlay for protection would be justified than in the case of an unexposed building. For instance, a building on a cliff over a valley followed by storms would be in much greater danger from lightning than a building located in the valley. This would be especially so if connections were made from the upper building to water level. Lightning rods can be arranged to give almost ideal protection when the expense is warranted. In the case cited above, a lightning rod located on the cliff would give good protection to buildings in the valley. It is probable that except for buildings in exposed positions and for special cases as magazines or oil tanks, the cost of even an inexpensive rod is not warranted from the standpoint of the cost of insurance.

SPARKS INSIDE OF METAL TANKS

Tests have been made to determine if it is possible to cause sparks inside of metal tanks or cans by direct stroke or by electromagnetic

induction or electrostatic induction. It has not yet been possible to obtain sparks between points within a completely closed metal tank. Under certain conditions small sparks have been obtained by electromagnetic induction between points in partly inclosed metal structures. Sparks are readily obtained within tanks from a grounded conductor brought in from the outside when it is slightly insulated from the tank by oxide or otherwise. The spark occurs by electrostatic induction or when either the wire or tank is struck. This is interesting in that sparks may be obtained from a grounded conductor.

The above experiments have a practical value, because they show the danger of any lead-in conductors to oil tanks or magazines. They also illustrate the importance of having no projections within a tank. For instance, a metal rivet insulated from a tank by oxide might cause a sufficient spark to ignite gases within the tank. Grounded gauge chains could readily cause internal sparks.

FIRES BY LIGHTNING

It is quite possible to cause fires by lightning by sparks between isolated metal parts even when direct strokes do not occur. Some model bales of cotton were placed under the model cloud. It was found that the cotton could be ignited by sparks electrostatically induced between the metal bonding strips.

CHEMICAL ELEMENTS AND ATOMS[1]

A LECTURE DELIVERED IN HONOR OF PROF. BOHUSLAV BRAUNER

By G. URBAIN

The Czech Nation, free and enthusiastic, after the long eclipse which it suffered, has resumed again the temporarily broken thread of its glorious past. It has regained its political, economical, and intellectual liberty. Its traditional genius has broken its shackles. But despite its temporary subjection, it has never ceased to be active. The flame of its genius has constantly burned, despite the storm which threatened to extinguish it. Honor will be forever due the Czech University at Prague which has striven unfalteringly and without weakness to transmit it to the present generation.

Bohuslav Brauner must be cited among those who have devoted their lives and energy to the sacred cause of greatness, of conservation of ideals, and of progress in the domain of physical chemistry. Among the chemists of other lands, friends of the Czechs, his name is symbolic of the scientific acumen of a race which can be unhappy with nobility, and being insuppressible, can not be enslaved. Surely the name of Bohuslav Brauner belongs to international science; but to French ears it has a certain vigor, suggesting intellectual independence, which is thoroughly Czech.

For a quarter of a century, my dear Brauner, we have been related in scientific and personal friendship. Thus I have been able to appreciate the grandeur of your vision, the integrity of your character, and the many other qualities that I could enumerate did I not fear to hurt your modesty. I will at present speak solely of your scientific attainments.

An idealist, you have good taste to the highest degree, and your disinterestedness is absolute. In an epoch when the spirit is at times too practical you set a high standard. You love science for itself, for what it reveals of the illimitable riches of the universe, for what it contains of harmony and logic. The solution of the problems which nature sets for us arouses in you true philosophic thought. Most of us are concerned with what science can do to

[1] Translated by permission from Reçueil des travaux chimiques des Pays Bas, 44, pp. 281–304, 1925.

help industry, seeking only for special results. Your enthusiastic and generous spirit cares only for knowledge. It was for that reason that when as a young man I had the good fortune of making your acquaintance, I was charmed at first sight. Our long correspondence, far from altering those first impressions, confirmed them into a definite judgment.

None of the large currents of ideas which have furrowed the scientific onward flow of our times has found you indifferent. You have been interested in all of them; have followed them when you have not been in the front. It has been not only with kindliness that you have looked into the first researches of the younger scientists. From my own experience, you have not been sparing in your encouragement and have guided them with good counsel. In science you have been not only a creator but also an inspirer. Your personal influence has passed beyond the frontiers of your land. Inspirer—that is the title which fits you, for it hints the radiance of a creative power.

A savant, without doubt, can know of no greater joy than to see assembled about him in worshipful mood his disciples and friends. I bring to you, my dear Brauner, not only proof of my own personal admiration and affection but also that of a great number of distant friends. The Chemical Society of France expresses through my voice the feelings they have for their honorary member. I am very proud of this mission as the authorized representative of this French society, for within it has been developed during more than half a century a large share of international chemistry. On many an occasion there has been presented before it to the scientific world important results due to Czech researches. It pays homage to your scientific work and takes pleasure in giving you public testimony of its great esteem. This homage is addressed to you very personally; it would have been given without regard to nationality. But the French have always been friends of the Czechs, and to-day that friendship is doubled through an alliance, a reciprocal gauge of security. Now that a sincere desire for peace and justice at last appears to influence the world, such an alliance should prove a mutual aid in the economical and intellectual evolution of the two peoples. The French chemists wish to forge between themselves and the Czech chemists intimate bonds passing the bounds of friendly courtesy. They feel convinced that you share the desire. Such intimacy will favor the growth of international science and through that aid in the development in all nations of the germs of reciprocal esteem.

Finally, the president of the International Commission of Elements renders homage to its dean, who has been one of the most

active members and who inaugurated the era of high precision in the determination of atomic weights.

Your work upon atomic weights is universally appreciated and probably better known than that upon the rare earths. Its objective is broader. Your merit and high scientific acumen came into relief with the publication of your admirable study of atomic weights found at the beginning of Abegg's Encyclopedia of Physical Chemistry. What striking honor this was to a Czech scientist.

The International Union of Pure and Applied Chemistry bore in mind this work at the very outset when they came to naming the members of the Commission on Chemical Elements and later when choosing the president of the subcommittee on atomic weights. I recall that Guye, whose ideas upon atomic weights did not wholly agree with yours, insisted that the presidency be given to you. Such acts of courtesy in all impartiality on the part of opponents show the value of a man. The two incidents just recalled show how universally you are recognized as the master in the domain of atomic weights.

An especially important task devolves upon the president of the commission. He drafts the report and prepares the table of international atomic weights. He must know the relations existing between the diverse atomic weights and judge their relative importance. He must be able to appreciate the relative worth of the values determined by various men. To bring such a delicate task to a proper conclusion requires good scientific judgment, a judicious, critical spirit, and an impartiality overlooking the rivalry of differing schools.

Now, shall we recall briefly our common recollections of the wonderful journey which we have made through contemporary scientific history, more especially through the domain of the chemical elements? In an epoch when time is no longer considered as immutable, we have surely lived existences which, measured by the importance and number of events which we have seen unroll before our eyes, have been the equivalent of several generations. Judging by you (Brauner) the limit of the youth of the spirit has been greatly extended. Scientific evolution has been a part of the change. Our times are privileged. They have seen many important problems proposed, a number of which have had surprising solutions. We have traversed the enormous distance which separates the elements of Lavoisier and of Berzilius from the isotopic constellations of Aston. With Bunsen you saw the birth of the first spectroscopic elements in the flame. You have contributed to the genesis of those elements recognized through their absorption spectra, for you were the first to see the element called praseodymium. A collective error, which

I hope is passing, does not attribute to you the fatherhood of it, but when the history of the element is written completely and impartially, full credit will be given to your name.

With Crookes you knew the phosphorescent elements in the cathode rays; with Lecoq de Boisbaudran, you saw those revealed by the induction spark. In the arc spectrum you witnessed the birth of luticium. With Ramsay you saw the ninth column come into the classification of Mendeleeff, for the existence of which you have victoriously fought. In helium, neon, argon, krypton, and xenon you knew the astonishment which the existence of chemically inert elements aroused.

At that time we considered our chemical elements eternal, immutable. Doubtless we need not have been deeply philosophical to have recognized in the doctrine of Mendeleeff the thread of an evolutionary theory such as then dominated science and of which Lamarck and Darwin were the promoters. Was Mendeleeff really an evolutionist as to the chemical elements? I would not dare to affirm it, not having read all that this genial Slav scientist has written. I have known him only through what has been more or less correctly translated into French. But you should know and doubtless are the only one who could settle the point. On my part I have always thought that he was. For how can one know the analogies which Mendeleeff's table brings into relief, how recognize the family traits, those intimate relationships of chemical characters and physical properties, without supposing some mode of birth which requires certain elements to be like brothers and certain others to be like more distant relatives? Have not you and Mendeleeff added something to science which is not read in the printed text but which may be read between the lines? I am disposed to see here the source of that contagious enthusiasm which the periodic system has inspired in you. You should have been prepared to admit that chemical elements are born and die. But before photography and electrometry had given, through H. Becquerel, Pierre and Mme. Curie, their marvelous discovery of the radioactive elements, the evolution of elements could have been only a philosophical hypothesis with no real experimental foundation. With radium transforming into the gas radon, with radon in turn changing into other new elements themselves radioactive, the hypothesis of the evolution of the elements becomes a reality. The chemical elements lose their immutability, are no longer dead as considered by the scientists of the era just passed. They enter into an active life.

The old philosophical dream of our medieval ancestors comes from the distant past into a wonderful reality. We would be tempted to cry "miracle" were we not preoccupied with consigning to the

dump the ideas which these discoveries have rendered obsolete. We are indeed fortunate in having witnessed such great events.

I was especially privileged, for with my own eyes I saw the element radium born. Pierre Curie was my teacher, and gave me the incomparable honor of his confidence and friendship. I have seen Mme. Curie working like a man with great masses of pitchblende. I saw the first separation of the bromides of barium and radium; I saw the radiferous crystals shining in the darkness before the spectrum of radium had been observed. Every Sunday I went with Langevin, Perrin, Debierne, Cotton, and Sagnac into the modest home of Curie which then changed into a kind of intimate academy. There the master with his customary simplicity told his ideas and was as willing to discuss ours. What great problems we debated. The behavior of radium brought into question ideas which had become classic. The continuous delivery of energy from radium contradicted our fundamental scientific notions. Must we renounce the principle of the conservation of energy, for we then thought that radium remained unchanged? Were we to admit that radium continuously set free energy without the loss of any part of itself? Does its substance vanish in radiation? And if energy and matter are but different aspects of a same invariant must we give up the principle of the conservation of matter, that great principle of Lavoisier which we have considered the corner stone of chemical science?

Pierre Curie desired to avoid destroying such fertile principles. He leaned toward an interpretation which while respecting the work of the past, yet might account for the future. In the end, radium became for him—an hypothesis which has been recently revived by J. Perrin—not a generator but a transformer of energy. This element held captive a yet unknown form of energy and metamorphosed it in the α, β, and γ rays. But when Curie, with Mme. Curie, discovered the so-called radioactive deposits, which he called "induced radioactivity," it was evident that radium itself must undergo change.

When Curie found that radium continuously set free heat we were forced to believe in the failure of the conservation of energy. When his little electroscope automatically charged and discharged itself in the presence of radium, producing work at a constant temperature, we had to believe in the failure of Carnot's principle. If we rejected the spontaneous transformation of radium into other elements, we became party to the bankruptcy of thermodynamics. But the emanation (radon), which had the characteristics of a new chemical element, was evidently generated from radium. This emanation disappeared spontaneously, little by little, to appear as radio-

active deposits and helium. The principles of thermodynamics came safe and sound out of the fray, but that of the immutability of the elements was moribund.

We distinguish between elements which show radioactive characteristics and those which do not. It is nevertheless true that the radioactive ones are elements, and therefore we can not hold that elements are immutable.

The theory of the disintegration of radioactive bodies, due to Sir Ernest Rutherford, justly dominates modern science. The ideas which he postulates are to-day solidly founded. The phenomenon of spontaneous radioactivity is interpreted as the projection out of the atomic nucleus of an electron, a helium ion.

The electron, the carrier of the β radiation in which matter and negative electricity are identical, is now the smallest mass of matter known to science. Its mass at rest is one thousand eight hundred times less than that of the hydrogen atom. It plays a part in a great number of material phenomena not related to radioactivity. There is no chemical element which can not liberate electrons detectable by electrometric means. It is apparently a universal constituent of matter.

The helium ions which constitute the α rays have a mass approximately that of a helium atom and each carries two elementary electric charges equal except in sign to that of the electron. They can not be considered a universal constituent of matter, since all the atomic weights are not even approximately multiples of four. There is a tendency to consider them as being themselves composed of four hydrogen nuclei (or protons, actual atoms of positive electricity), representing four charges, and associated in the helium ion with two electrons for the necessary intra-atomic binding field of force. Hence the hydrogen ion or proton may be considered the second universal constituent of matter. Electrons and protons suffice to make up the assemblages which are our chemical atoms. This manner of postulating the building of the universe is admirable. It satisfies at the same time both the scientist and the philosopher. Its scientific character is undeniable. The existence of electrons is certain; they have been isolated by the most diverse methods, to which I believe there can be no serious objection.

The reality of protons is less certain. They must go through several small formalities before they are accepted in scientific society. They are tolerated, since their existence fills certain needs.

Only a little while ago several physicists were disposed to postulate that matter was composed exclusively of electrons. But it is difficult to conceive how masses of negative electricity could build neutral atoms and molecules. Positive electricity remains an enigma. It seems logically necessary that material negative par-

ticles must have neutralizing positive particles. The α particles of radioactivity seem to reveal such elementary masses, but we are still at a loss, for their mass is manifestly too great.

Sir Ernest Rutherford, to whom we owe what is basic in our actual ideas about atoms, noted that the α-radiation is the most powerful form of energy at our disposal. This led him to conceive the bombardment of the atomic structure with them. It is useless here to go into the details of his experiments with which you, my dear Brauner, are familiar. You know that by an irrefutable interpretation of the observed facts in the case of nitrogen, phosphorus, and several other elements, the atomic citadels had been breached by these projectiles and that the splinters resulting from the consequent explosions could be nought else but hydrogen ions. In thus declaring war upon the stable atoms, Rutherford formed a new branch of science showing artificial radioactivity, one of the greatest discoveries of our extraordinary epoch.

These experiments show that protons must be a constituent of some atoms, but it does not follow that they are a universal constituent of matter. But do you not think that at least provisionally we may accord them this privilege? If you make this concession we may mix with strict science a little pleasant philosophy: This existence of two chemical elements, the electron and the proton, out of which everything in the universe is made.

As to the simplicity of its conceptions, modern science thus rivals that of Aristotle. The ancients postulated four elements, we admit only two. The atoms of Lucretius have become a little complicated and those of Dalton have lost their primitive simplicity. Science has gained in unity and has to a certain degree attained the ideal which it has sought with varying fortune for 3,000 years.

Yet, though the universe has been reduced thus to two constituents, and the electrons and protons occur as the simplest reduction of our ideas, it does not follow that those ideas are perfectly clear. Berzilius, subsequent to the beautiful experiment of Davy, tried to explain matter through electricity and fabricated for the purpose one of the most curious syntheses which the annals of physical chemistry contains. I allude to his electrochemical theory of which the classification will remain an eternal monument. He knew nothing of the nature of electricity; for this he depended upon the wisdom of future physicists. We physical chemists of to-day do not tell what matter nor what electricity is. We merely know them as phenomena. The least metaphysical among us see in electrons and protons merely centers of convergence of lines of force. That evidently explains nothing fundamental. It makes for us a world formed of minute hairy points, the hairs strikingly abstract, only indicating to us the possibility of some phenomena.

Frankly, electrons and protons are monads. Leibnits thus lives again in modern science as Lucretius did in the science of Dalton.

I beg you see no blame in what I have just said. It is not necessary, it is perhaps impossible, that we should understand everything. The penetration of human insight possibly has limits. We should not expect present science to explain everything. Knowledge we should have. It should allow us to predict. Our ideas as to what is comprehensible or absurd are doubtless hereditary habits of our intellect. It is fortunate that science does not halt because of such considerations; it would then repulse as incomprehensible Newton's theories of actions at a distance, as the Cartesians did. Doubtless, the mathematician would never have had imaginary quantities which, being inconceivable, would be neither more nor less than absurd.

In the evolution of scientific theories there are surprising enough changes in the point of view. Take, for instance, Fresnel's optics where the light phenomena were pictured as analogous to the motions of the pendulum. The model expresses laws the phenomena show. The aptness of the explanation resulted from the closeness of the analogy. Imagination was satisfied. Then there is the reality which we were prone to accord to the ether of physics. But the younger school of physicists are against the ether because at the same time it must be more fluid than any gas and more rigid than steel. They look upon it as a resurrection into modern science of a fossil remain of the ancient fluids. They prefer to replace it by the equations of Maxwell or something as subjective. I wish that we might thus gain in reality what we lose in simplicity, but we must confess that there is nothing to be hoped for from the change.

As to the atom, have we attained something real or only a model symbolic of observed phenomena? It is difficult to say. The model which Bohr has elaborated from that of Rutherford shocks our former beliefs. For the electricity which circulates in the form of exterior electrons in that atom, does not obey the ordinary experimental laws of electricity in motion. We had learned that a displacement of an electrical charge is accompanied by radiation. But Bohr postulates privileged orbits wherein the exterior electrons may circulate without radiating.

Bohr, in making this hypothesis, breaks with a tradition of which no theorist has dared to neglect the laws. His immediate predecessor, Rutherford, had allowed the electrons to radiate since it was supposed the model must obey the standard laws. Bohr's models have their own laws with no necessary relation to the laws of ordinary experiments, and he thus turned scientific thought into a new and unknown direction. The models lose the explanatory charac-

ter we had expected of them. Bohr's atom is not a clear explanation, for the privileged orbits are not understandable in themselves; neither are the "quanta of energy," set free by the electrons in leaping from one privileged orbit to another. In the future are theories to be built upon such contradictions?

The atom of Rutherford, which is otherwise satisfactory, has the objection of unceasing radiation. In time it should wear itself out. Each outer electron must gradually approach the central nucleus of the atom, finally falling into it, which means its death. Of course, we must resign ourselves to death. We might have accepted the death of the stars without the optimistic invention of Arrhenius, but we can not that of the atoms; that would mean a definite end of the universe which we find it comforting to look upon as eternal. Bohr, in revivifying our hopes, is a great benefactor. Further, if the electron revolving about the positive center of the atom radiated constantly, matter should be always luminous, which is far from the fact. This seems a critical objection.

It seems necessary either to resign ourselves to not understanding, as Bohr has done, or to resign ourselves to a model in flagrant violation with experience. There is no doubt as to our choice. To one who finds fault that the electrons in their privileged orbits do not obey the laws of electromagnetism, we may reply that so far as known these laws relate only to large-scale phenomena. They may not apply to the electron or to the atom, but only statistically when a large number of them are under consideration. Men endowed with excellent individual qualities may make detestable crowds. Atomists take the Carnot principle as a collective law for which the little demon of Maxwell[1] has no power. Thus Bohr may be less revolutionary than he seems at first sight. He can intrench himself behind an illustrious precedent.

Our ideas relative to the older elements, which are really not elementary, have not reached the end of their vicissitudes. Radicals composed of electrons and protons they may be. On such terms they have lost nothing of their older significance in chemistry. Chemistry ceases to concern itself with the primary elementary forms. Its domain henceforth is one of secondary combinations now that its ancient elements have become divisible and composite.

It might be more philosophical to enlarge the realm of chemistry to include not only radioactivity but also electronics. But then we must cross the barrier which has separated chemistry and physics. The shadow of Auguste Comte would shake with indignation. The old modes of thought, molded by the routine of

[1] An imaginary being invented by J. C. Maxwell, who is supposed to witness the actual working of the law of thermodynamics, and to be able to control it.

professional habits, and the purism of academic methods, maintained long ago the difference between these two sciences, a distinction originally drawn by an arbitrary classification which divided into compartments the continuum of the sciences.

When our knowledge was less, it was easy to give the chemical elements a simple and apparently decisive definition as Lavoisier did. To respect his definition, at least formally, it would be necessary to-day to distinguish between two methods of analysis, that of chemistry and that of physics. To the contingencies involved in the very nature of things there are then added artificial limitations. When we form a scientific ideal we should weed out these conditions as much as possible, no matter why they were imposed.

Lavoisier, in order to define a simple body, had to clear away the vapors of phlogiston and renounce the ideas of a then decrepit atomism. What would he have thought of our present ideas and theories? Would the numerous presumptuous accumulations in favor of the atomic structure suffice to prove its reality to him? He, and all the encyclopædists of the eighteenth century, would have reproached us, perhaps, concerning this imagined existence of atoms, this act of faith.

The atoms, so far as any direct manifestation to our senses is concerned, will aways elude us because of their extreme minuteness. We can not ever hope to see them because we know beforehand that our microscopes, and even our ultramicroscopes, however powerful they may be, have a very limited magnification which would always be insufficient. In this direction the matter is definitely settled. We must be reconciled to the certainty of never seeing them and be contented to know them through their effects. In taking these evidences we are like a judge before the accused, and we must fear errors of judgment. The multiplicity of the accusing evidence is doubtless very impressive. Is the question clear enough so that we can give a certain judgment?

We consider effects since they are our sole evidence. Then we postulate the atom that we may the better interpret these facts—in no way making the atom a necessary objective reality. Jean Perrin, who has gone deepest in this matter, has appealed to probabilities. How did he prove the reality of molecules in his now famous memoir? Doubtless he has applied very precise exponential laws resulting from direct experiment. But it was not with molecules themselves that he experimented, but with colloidal aggregates which he called composite molecules. Without doubt he may diminish more and more the diameter of these aggregates, but there remains a gap between the smallest of them and the molecules which he may never close. When he counts the molecules in a vertical cylinder of

hydrogen, it is by following the capricious trajectories of gamboge particles.

He probably would not have been concerned with this gap in his demonstration were it not that his scruples made him wish to close it up. He has accumulated excellent presumptions which he has attached to these least apparent parts of our universe. He did not limit himself to those pseudosolutions just mentioned nor to radioactivity. Following Lord Rayleigh, he asked the question of the blue of the sky. He gathered 15 independent ways for the determination of the constant N, which he modestly called Avogadro's number.

His experiments in this direction are doubtless the most extended that have been made. But he has been able to conclude only that the existence of molecules, and therefore of atoms, is exceedingly probable. In reviewing the matter in most diverse aspects he showed that it is indispensable for coordinating our knowledge. If he has left an indefinitely small amount of doubt as to the reality of the molecule and the atom, he has at least made us like them. He has shown that at present science and poetry—fact and fancy—are not irreconcilable. He has passed on the tradition of Laplace, of Alembert, and of Fontenelle. His spirit fraternizes with that of Lucretius and the bees of Hymettus have placed their honey upon his lips.

Is it necessary to seek the reality of the atom in the absolute manner of the philosophers? Are not molecules and atoms syntheses which embody the fundamental laws of chemistry and a large part of those of physics? Their reality (as J. Perrin indicated in the last edition of his book on atoms, pp. 294-295) lies in the relationships they allow between phenomena which, without them, we would never coordinate. Were we to strike out to-day from the scientific vocabulary the terms atoms and molecules, all physical-chemical science would disappear, leaving only a dry list of facts impossible to connect one with another.

The reality of the atom is doubtless relative, but it is probably for the best. It has been justly said that absolute philosophy gives way more and more to relative science. Time is a good example. It allows us to give the atom a relative existence.

The extreme complication of modern science carries subtleties which we who sit on the school benches may ignore. It is repugnant to mix these philosophical matters with positive facts. The facts come to us mixed with no hypotheses, and here we find a criterion of the truly scientific mind. How difficult it is to attain it! We are given the definition of a chemical element according to Lavoisier, but we talk of it in a very different way. The ultimate

term of analysis, the body from which we can take nothing but itself—all that is far away.

Such a definition can not be taken literally, for then the greater part of the oxides of the rare earths would be elements, since they can not be reduced. One rather feels that the definition of an element should not be submitted to the contingencies of analysis. We should define elements by characteristics which belong to them and we have carefully felt our way for a long time through the uncertainties of analogies. The isolation of an element in its metallic state is no longer necessary to characterize it as an element and we must have recourse to elementary characteristics. This leads to two necessary conditions:

(1) All compounds of the same element must have in common certain characteristics.

(2) Among these we can retain only those which are general.

The lapse of time makes possible an accurate statement of the problem. In the earlier times to which we have alluded, a more or less confused intuition served as a guide.

The chemical equivalent, the proportional number, the atomic weight, call it what you will, is manifestly insufficient because, though satisfying the two preceding criteria, cited for the case of pure elements, they also hold for certain compounds, for example, the rare earths, of which we can measure the molecular weights, a measure scientifically precise but, in the present instance, of little meaning except to a specialist. Hence the two conditions given, though manifestly essential, are not sufficient. It is further necessary that the characteristic be independent of the state of the body examined. Bunsen discovered in the spectrum the first strictly elementary characteristic. Until then the elements had been simply chemically elementary; henceforth they will be spectroelementary.

The method of flame spectra had an astonishing success. There came at once the discovery of rubidium, caesium, and then almost immediately afterwards, of thallium and indium. However, it did not prove to be a wholly general method. Indeed, there are besides the alkaline metals and alkaline earths very few elements susceptible of being revealed by the flame. Do you not recollect that when Bunsen undertook with Bahr the study of yttria he found only yttrium and erbium among the elements of Masander? He then gave all the weight of his authority against the existence of terbium, a phantom element, denied by Cleve, asserted by Delafontaine, and which owed its definitive resurrection to Marignac?

The technique of spectrum analysis, then too primitive, needed development. Thalen, and then Lecoq de Boisbaudran, had recourse to the electric spark, which led to a much more general method.

It seems to me that to Thalen belonged only the credit for better delineating the group of the rare earths already discovered. Lecoq de Boisbaudran, an intrepid worker and extraordinary observer, discovered gallium.

This name, my dear Brauner, should recall the triumph of the cause which you defended, for gallium seemed to be the eka-aluminum which Mendeleeff had so exactly predicted. I was a friend of Lecoq de Boisbaudran. He gave me great encouragement in my researches on the rare earths at a time when I greatly needed it, for you know from your own experience how many such researches are deceptive and what perseverance they require. Lecoq de Boisbaudran had genius and a great soul. I have always been surprised that he opposed to the great foresight of Mendeleeff the very interesting, but very restricted, personal considerations upon the constitution of spectra which he asserted had been his only guide in his researches on gallium. His method of the uncondensed spark allowed him to place in their proper order gadolinium and ytterbium, which Marignac, the last representative of a brilliant group of chemists, had discovered by the older methods of pure chemistry.

Marignac would have closed the chapter of the discovery of elements by purely chemical methods had not Winkler had the good luck to analyze argyrodite and find in that very rare mineral, germanium in large quantities. Henceforth we will expect to find all the new elements discovered by the methods of physics, more especially through spectroscopy, the technique of which has been adopted in several chemical laboratories.

No one doubts that spectra are well adapted as an elementary character, presenting characteristics identical in all the combinations and mixtures of an element. There have indeed been attributed to spectra more value, more constancy than they really have. All kinds of spectra—those observed in solutions, in phosphorescent cathode spectra, those in the electric spark between solids in vacuo—are considered of the same worth as elementary characters.

You, my dear Brauner, inaugurated with the rare earths that remarkable epoch in which absorption spectra played the principal part. Then, afterwards, Lecoq de Boisbaudran discovered samarium and Marignac gadolinium while you established the compound nature of didymium.

In 1882 you decided very tardily to publish the results of your important researches. Certain variations in the absorption spectrum of didymium had been noted by such men as Delafontaine, J. L. Smith, Lecoq de Boisbaudran, and then by Cleve; but they were inclined to attribute the variations to differences in acidity of the solutes. Having eliminated that source of error, you deter-

mined that in certain of your fractional solutions of didymium, certain bands in the blue region—particularly the group of bands, λ=449 to 443—had a special importance, equaling in intensity the group in the yellow—λ=590 to 568. At first you attributed them to lanthanum, but later knew that this element took no part in the phenomenon. Now it is certain that the blue band belongs to praseodymium and the yellow to neodymium. Thus, von Welsbach, to whom the discovery is generally attributed, was really later than you in the separation of these two elements. I am not surprised that the honor of the discovery was attributed to him, for in such matters the scientific world is indifferent and allows itself to be misled by appearances.

One would be very incompetent to wrongly estimate the results of your researches. We forget too often that in order to judge the value of a discovery it is necessary to consider the conditions under which it was made and make proper allowance for the progress science has made since. Within our times ideas have developed rapidly, and experimental technique has been improved with inconceivable rapidity. The two processes have been mutually helpful.

The 25 years I have spent in the study of the rare earths give me the right to affirm that it would have been impossible in 1880 to have pushed farther than you did the researches on the separation of didymium. Didymium was very rare, the methods of fractionization very rudimentary, preventing you from carrying the separation very far; but that should mean more credit for obtaining the results then, than for perfecting them later.

Those early days were days of misery in the study of the rare earths—I have known in comparison only days of relative opulence, and I salute you, my dear Brauner, one of the pioneers whose work has always filled me with admiration and profound respect.

Somewhat later there occurred in the domain of the rare earths a very orgy of spectrum variation. Your immediate successors seem to have endeavored by their excesses to discredit the work of their predecessors. The spectrum bands seemed to lose all orderliness. Your neodymium and praseodymium, the samarium and the dysprosium of Lecoq de Boisbaudran, the holmium of Soret and Marignac (and not of Cleve, to whom it is often attributed), the erbium of Mosander, and the thulium of Cleve, in short all the elements of the absorbent-spectra group, seemed to multiply ad infinitum. Krüss and Nilson, H. Becquerel, Crookes, and all the world with them, noted the variations in the intensity of the different absorption bands in ever-changing proportions. Each one wished to discover and believe he had seen a new element. Such

discoveries became so common that instead of names they attributed provisory notation, be it to the bands or the supposed new element. When they had used up the Latin alphabet recourse was had to the Greek which in its turn would apparently fail. The rare earth elements came in swarms. They became no longer a group but a whole fog. Finally, since a halt had to be made somewhere, Crookes pronounced his famous aphorism, "a band, an element."

The subject grew chaotic; but even this chaos was not sufficient. Spark spectra were brought into the fray. Lecoq de Boisbaudran exhausted the alphabet to z and Demarcay the capitals of the Greek alphabet. Then the phosphorescent cathode added their quota which again required the use of two alphabets. It took the brilliant imagination of Crookes to build upon his first beautiful discovery the wonderful edifice of meta and ortho elements. Ortho elements broke up into meta elements. The structure of clear ideas so carefully built until then was in danger of shipwreck. The yttria earths, with Crookes at the helm, were sucked into the whirlpool along with samarium. His fertile imagination amalgamated the most bizarre ideas with those of a genius. Departing from reasonable points of view, he compared spark spectra with phosphorescent spectra. Experience later refused to justify the step he then took in assuming that both spectra obeyed the same laws.

Since spark spectra augment in intensity with the increase in concentration of an element he assumed that the same would happen with phosphorescent spectra. His conviction was so strong that he made no experimental trial to justify an analogy which to him seemed evident. Further, while he was astonished at the sensitiveness of his cathode spectra, he did not note that that of the spark spectra was very limited. Indeed, his technique in the case of spark spectra differed little from that of Lecoq de Boisbaudran, which did not permit the observation among the yttria earths of any but gadolinium, dysprosium, ytterbium, and, of course, yttrium. In fact, Crookes could observe only yttrium. The spectrum appeared constant to him, while he found great variations in the atomic weight. From this he felt it right to assert that yttrium, an element as indicated by its spectrum, had a variable atomic weight. He was not the only one of this opinion. Greatly influenced by Hinrichs, who criticised severely the work of J. S. Stas, the dogma of the constancy of atomic weights singularly staggered in this period of equivocation. The various portions, in the fractionations of Crookes, identified by their spark spectra, differed in their phosphorescent spectra. Therefore they were characterized by Crookes as distinctly different atoms of the same element. They were called meta elements of yttrium.

It surprises me that Aston considered this theory as a prophetic vision of isotopy. For my part, I attribute only to chance any analogy between the two theories.

The experiments of Crookes relative to meta elements had the incontestable merit of bringing to light a series of remarkable phenomena then entirely novel. Would that he had then listened to the wise counsel which Marignac gave him so diplomatically and courteously in the Journal of the Natural and Physical Sciences of Geneva. Why did he not mind the objections with which Lecoq de Boisbaudran so justly opposed his theory, and which proved so clearly that the phosphorescent spectra of yttrium did not belong to yttrium but to impurities? The criticisms of Marignac and Lecoq de Boisbaudran appear to have been met with general indifference. Indeed, the theory of meta elements was very favorably received. Crookes did not lack either approval or imitation, but to-day the meta elements have no standing. Of the long discussion which I had with Crookes on the matter, there remain to-day only the general laws of cathode phosphorescence.

The passing interpretation of the facts matters little in comparison with the real observed phenomena themselves. The work of Crookes on the phosphorescence of the yttria earths is a lasting monument. This we can admire without reserve, closing our ears to the interpretation. I regret only that my illustrious opponent lost through his mistaken theories the advantage of an important discovery, for unwittingly he had come upon europium. I would be happy could I save this from oblivion. Crookes had observed in the mixtures which contained both samarium and yttrium, and which consequently should contain all the intermediate earth elements, a phosphorescent band which appeared to him to behave in a peculiar manner. He designated it for that reason an "abnormal band." At the time he attributed it to both samarium and yttrium, considering it as a resultant vibration of the atoms of the two elements. Lecoq de Boisbaudran, who found several analogies in certain phosphorescent spectra of solutions, which he designated "reversed spectra," attributed the band to a new element. He said that this band "was perhaps not without relationship to the abnormal band of Crookes." That is definite enough. Thus Crookes was left free to vindicate himself in the discovery of this new element. He remained contented to consider his band as characteristic of a meta element of samarium.

Among the earths which showed him the reversed band, Lecoq de Boisbaudran observed a new spark spectrum; but he reserved the question of deciding whether or not it was identical with the element showing the "reversed spectrum" or that which produced the direct spark.

Demarcay, who commenced the utilization of the ultra-violet region for spectrochemistry, announced an element which he designated as Σ. He later recognized the identity of this with that which the spark had revealed to Lecoq de Boisbaudran, but he had some reservations as to the origin of the anomalous band of Crookes. He finally called the new element europium. He isolated it in a very pure state but was unable to complete his work.

Having had the good fortune to isolate europium almost quantitatively, I am able to clear away some of the uncertainties relative to the diverse spectrum characteristics at first observed. Particularly it was apparent that the anomalous band of Crookes and the reversed band of Lecoq de Boisbaudran were different manifestations of this element.

Certain that europium had been first revealed to Crookes, I sent him my results before publication, together with a sample of pure europium. He made a magnificent spark spectrum from the sample—he had much perfected his technique. He published that spectrum which had no immediate relationship with the phosphorescent band and claimed nothing.

Almost all elements have striking histories but europium would have beaten all records if celtium had not been subsequently discovered.

I will not develop further the history of the rare earths. The many elements of the group have been isolated one by one, and their characteristics fixed with surety. You know as well as I, my dear Brauner, the closing chapter of their history since you wrote it with all the necessary detail under circumstances unforgetable to me.

During the years which closed this history, Sir W. Ramsay opened and closed a new column in the classification of Mendeleeff, discovering successively the different rare gases of the atmosphere. Curie and his pupils, Sir E. Rutherford and his collaborators, several years later demanded from the electrometer, what, until then, had been asked from chemistry and spectroscopy. We know some 40 new radioactive elements. These we may call electrometric elements for we can observe the spectra only of radium and radon.

When it was established that the radioactive elements are born and die according to exponential laws, the composite experimental decay of mixtures of radioactive elements, not in equilibrium, was ingeniously analyzed into the components due to the separate elements. Each one of these new components presumably belonged to a new element. The discovery of elements in this field became thus the analysis of curves. It is difficult to avoid certain scepticisms; and those who have for a long while made elaborate chemical analyses in order to find evidence of new chemical characters may

well be excused from thinking that new generations may discover now unknown elements. Since each new radioactive element is characterized not only by the length of its average life, but also by the coefficient of absorption of its radiation, and finally by the velocity of its α and β particles, the multiplicity of these characteristics and the manner in which they behave under chemical influences leave no further doubt upon the objective reality of the most elusive of the radioactive elements.

Their multiplicity alone is disconcerting. It is evidently impossible to put each one of them into a separate compartment of the too few compartments of Mendeleeff's classification. Must we, therefore, renounce the universal application of that classification and exclude from it the majority of the radioactive elements? You, Brauner, who have identified yourself with Mendeleeff's cause and have struggled so much for the success of the periodical classification, how anxiously you must have considered the matter. When it became evident that certain elements distinct in their radioactive properties, could not be distinguished in other ways, they were naturally grouped in the same compartment—that is, all those which appeared chemically the same. This phenomenon Fr. Soddy called "isotopy." This new notion, the value of which has become considerable, at first seemed to arouse only a limited scientific public. For most chemists, ionium, which could not be separated chemically from thorium, ultimately, could only be thorium particularly affected through radioactive qualities. It did not seem of good augury that two elements could not be separated even slightly; and yet further, their luminous spectra seemed to show no differences. The daring of Soddy did not seem very great to have thus simply settled the matter. If, as we once admitted, an element is sufficiently defined through its spectrum and the value of its atomic weight, one could not at all doubt that ionium and thorium were one and the same element. Then in each compartment of Mendeleeff we would put only one element where the radioactive people would group several.

The ideas of chemical and radioactive elements seemed to be in conflict. The chemists were inclined to concede as little as possible to the physicists.

It is true that the matter of the affiliation of the radioactive elements was not then very clear. It was difficult to put order into the labyrinth of radioactive bodies. Fr. Soddy finally brought the desired thread of Ariadne in the guise of the law of displacement which gave a definite means of classifying a radioactive element in the periodic scheme when we know the nature of its radiation and its immediate ancestor. The same laws were also stated at about the same time by Fajans.

Such important laws could not pass unnoticed even by the eyes of those who did not especially work in radioactivity. All which relates to the periodic classification thus again assumes a general character and interests both chemist and physicist.

In what relates to radioactivity, experiment and theory are so intimately bound that it is difficult to tell where one ends and the other begins, and one willingly attributes to theory the preponderating part. We seek for the crucial experiment which dispels all doubts. Radioactivity is found in two series in the Mendeleeff classification, and theory assigns to the changing element one of two ultimate forms—helium or lead.

I spoke earlier of variable atomic weights. Th. Richards who obtained for lead from galena the atomic weight of 207.18, found for lead from carnotite the value 206.41. The precision of these measures was over 1 part in 10,000. There was no chance for doubt. We must applaud him.

There therefore exist different kinds of a body as common as lead. This name then does not designate one but a family of substances. Our atomic weights which served as bases for our highest theoretical speculations can not be considered as true constants since they characterise not pure bodies but mixtures. Once more we must make an alteration in our definition of an element.

Will the classification of Mendeleeff totter now that its foundations seem wrong? How shall we connect the properties of an element with its atomic weight? It is necessary to give up the rigor of the atomic weights and resign ourselves to their being only average values. The idea of Fr. Soddy comes as a great relief in the eyes of chemists. Mendeleeff's classification no longer should be considered as dealing with elements but rather with families of elements. Each family becomes a pleiad of elements, in the limiting case, an element. The idea grows on us. It is in the scientific air which we breathe. We are anxious as to how in actual experience it will turn out with all the elements, for until now the trials have all been with radioactive elements. The abnormal leads, studied by Th. Richards and his associates, by Maurice Curie, by Baxter and Grover, by Hönigschmidt and Horowitz, by Soddy and Hyman, and several others, were all radioactive. In the special domain of radioactive elements, the existence of isotopes has passed the boundary which separates probable hypothesis from certain reality. But what next?

Whatever value we may be disposed to attribute to this distinction we are only half satisfied. Some of the compartments of Mendeleef are to contain families—e. g., in the case of the radioactive elements—and others single elements. Is it necessary to save the classi-

fication at the expense of this heterogeneity? We can not believe that a moment. On the other hand we should be certain of the value of the classification in itself. It is not the question of saving it from a disaster by which it is not menaced, but to restate the principle which certainly contains something of truth although not the whole truth.

We have heard on many occasions of atomic numbers. First through Rydberg but especially through Moseley. The latter gave us a remarkable law which connects the radiation of the X-ray spectra of each element with its atomic number. But this number designates only the place occupied by each element in the classification. It has in that sense only as much signification as the principle of increasing atomic weights, one already put to rude test by the respective positions of potassium and argon, iodine and tellurium, nickel and cobalt, so that in this its interest might vanish. The atomic numbers are in themselves only a series of whole numbers without any precise signification. After all, the law of Moseley is only an approximation, since it expresses as a linear relation what experiment shows us more and more is curvilinear.

One could believe in 1914 (and I sincerely so believed after my stay at Oxford where I worked with Moseley) that, in substituting for the atomic weights the atomic numbers, Mendeleef's theory had a real improvement. Indeed the atomic numbers, susceptible of a measure sufficiently precise according to the distribution of the X-ray in the scale of wave lengths, succeed each other in the definite order conforming precisely to the place occupied by the element or family of elements in the periodical classification. Argon is in its proper place preceding potassium; tellurium and cobalt on the one hand and iodine and nickel on the other are in their proper ranks. All difficulty vanishes. The theory comes out triumphant and strengthened from the test.

However, the curvature of the lines of Moseley throws a shadow upon the picture. We might think to find in this succession of whole numbers a certain mystical value. The virtues in numbers which the ancients held has been vigorously decried by philosophers, and their ideas are echoed in modern science. But there is a physical significance to the numbers of Moseley. Sir E. Rutherford takes one from the experiments of Chadwick on the diffusion of the α-rays. But the process is not wholly physical except so far as theory goes, but from a more general point of view metaphysical. On the one hand the diffusion of the α-rays through a body can lead to the atomic numbers following the ideas of Rutherford; on the other hand these numbers represent the number of positive charges on the nucleus of each atom, or further, the number of electrons which revolve about them. The atoms of Rutherford inspire us with

utmost confidence since he has found the way of making them exemplify all the laws necessary for the sustaining of our science. We can declare ourselves satisfied. The classification of Mendeleeff has now solid foundations. It can await new facts and feel equal to them. To have seen it thus in the past come out the stronger after each fray, we feel all the more confident in its fate. Glory to Mendeleeff, and glory to you, his most ardent disciple, glory to the founder of comparative chemistry.

It is good to have found a scientific base for this study of chemical analogies. Strict science did not require it, but the demon of curiosity which is within us desired it. Between you and me, I believe we are always like children and ask "Why?"

"Why" do chemical analogies exist? Take the case of electrons. When half of the universe is made of electrons they have to assume many responsibilities, especially when the other half shrivels up, so well protected from experiment that it refuses to play a part in the phenomena which, except for radioactivity, are just beyond our ken. "Electron" answers all "whys" of physics and chemistry. They have much to do.

Maybe we have only translated into a new language, very poetic and full of imagery, the questions which our demon of curiosity poses for us in a very prosaic language. We, indeed, express to-day the same idea in saying either dysprosium and holmium are very closely related, or the atoms of dysprosium and of holmium have both several circlets of exterior electrons. If our demons give the second statement in the form of a question we may be sure the first will be the answer.

We have here, then, as a mathematician would say, reciprocal propositions. Let us hope for their proof. Meanwhile we say that two distinct atoms with identically the same circlets of exterior electrons behave chemically and physically in the same manner. Thus we interpret isotopes. It little matters whether they are radioactive or not, the idea of isotopy has become general. It was inevitable.

Among the nonradioactive elements, isotopy was, during its period of incubation, only an elegant interpretation of a new spectroscopy due to the inventive genius of J. J. Thomson. He dispersed in a Crookes tube, the canal rays—that is, the positive rays—by means of a double field, electric and magnetic. He thus obtained parabolas due to atomic trajectories which were so great in number and of such quality that in order to interpret them it was necessary to consider our elements as mixtures impossible to separate by any other means.

The experiments of Aston upon neon brought a real explanation of the variation of density of neon in fractional osmosis.

Subsequently, making perpendicular the two fields which J. J. Thomson used for the deviation of the positive rays, Aston has shown that at least a third of the more common elements must be looked upon as mixtures of isotopes. The fractionation to which Hevesy subjected mercury vapor showed clearly the multiple isotopy of that element. I am sure you have been glad that isotopes are not absolutely rebellious to the methods of analysis which are generally considered chemical. It remains to be said that the spectra of isotopes are not strictly the same, which doubtless you hoped would be the case. We now have abundant proof.

If the isotopes can be separated chemically (time and the necessary efforts are negligible conditions from a theoretical point of view), and if they have different spectra (it will be necessary only to have recourse to the sixth order in the echelon spectroscope of Michelson or the interferometer of Fabry), we do not see why they should not be called elements. It is clear that they are. Between them and the individuals of a group of elements like the rare earths there is, to you and me, only a difference of degree in the analogy.

In this it seems that we misconceive the rights of the electrons which give the primary significance to the atomic number, which is all important in the defining of a chemical element. Each element of the group of rare earths has its atomic number, and there is only one atomic number for all the elements of an isotopic group. Have we a sufficient reason for defining an element by its atomic number? Is it right to define the group rather than the nature? No agreement has yet been reached. But if we are now beaten in the search for the proper definition some day we will certainly find it.

The International Commission on Chemical Elements, it is true, has defined the element through its atomic number. That is a victory for the periodic classification which should somewhat satisfy you. The definition has been given only a provisory right, a concession which should please you.

It is time I should close. I could not pretend to exhaust the subject which I had the audacity to commence. I have tried to recall certain memories. Perhaps I have been too personal. A historian should avoid all sentiment, which a contemporary does with difficulty. A reticence is required which I lack.

I could not speak as a professor and take a dogmatic attitude in the presence of a master like you; indeed, such an attitude is never mine. Wherefore I have spoken as a narrator and friend. If aught lasts of this talk I wish that it might be the memory of the great friendship with which you have honored me, my dear Brauner.

THE MANUFACTURE OF RADIUM[1]

By Prof. Camille Matignon,
Collége de France

[With 4 plates]

HISTORICAL

Mme. Curie announced before the Academy of Sciences at Paris on the 12th of April, 1898, that two uraniferous minerals, pitchblende and chalcolite, showed more intense radioactive properties than should be due to the uranium they contained. This remarkable fact, she added, led to the belief that these minerals should contain an element more radioactive than uranium.

M. and Mme. Curie—at times in collaboration with M. Bémont—by the chemical analysis of pitchblende, showed successively the existence of two new radioactive elements—polonium, which follows bismuth in the course of analytical processes, and radium, the element next to barium.

Radioactivity, discovered by Henri Becquerel, thus proves to be a direct method of chemical analysis of hitherto unexpected sensitiveness for indicating the existence of radioactive elements and serving as a guide in their separation.

The treatment of a ton of the residues of pitchblende, under the chemical supervision of M. Debierne, enabled M. and Mme. Curie to isolate a small quantity of radioactive matter associated with barium. This, by successive separations from the barium, became enriched little by little, so that the spectroscope showed clearly the elementary character of radium. In 1902 they obtained a strictly pure chloride of radium.

During the progress of this work of separation, M. and Mme. Curie demonstrated the curious and novel properties of this new element—its radioactivity, induced radioactivity, physiological actions, etc.

Pitchblende, an uranium and radium ore, is found in a well-known mine of Joachimstahl, in Bohemia, where it is regularly treated for the extraction of the uranium. The small amount of uranium salts used throughout the world comes from there. During this extrac-

[1] Translated by permission from Revue Scientifique, Aug. 3, 1925, pp. 524–532.

tion the radium becomes concentrated in the residues. These residues, accumulated since the beginning of the uranium industry, were the first source of radium. The mine was owned by the Austrian Government. In order to have a monopoly in the manufacture and sale of radium, the export of the mineral was prohibited. A radium institute was founded in Vienna for the development of the applications of radium.

Attention everywhere was directed to the known veins of uraniferous minerals: those of autunite in Portugal, of pitchblende in England, in the Cornouailles, in Schneeberg, and Johanngeorgenstadt, in Saxony. At the same time, search was instituted for new veins. Subsequently pitchblende was found in the United States of America, in Mexico, and in the Indies, where it was exploited for a short time.

The most important find was that of a very rich vein of carnotite in the United States, extending in a mountainous and wild tract through the States of Colorado and Utah. Influential American enterprises, despite the small content of radium in the mineral, did not hesitate to establish, in those desert regions, roads and works with companies of workmen for exploitation because of the immense extent of the veins.

The project was so successful that in 1912, 1,200 tons of carnotite, containing 8 to 9 grams of radium, left the United States for France where a radium manufactory had been established in competition with the Austrian works. From this time on, the exploitation of the mines developed rapidly, and at the same time works for the refinement of the radium were established in America, so that 10.5 grams of radium were produced in 1913 and 22.4 grams in the following year. The exportation of carnotite to Europe continued up to the outbreak of the World War in 1914. In 1913 and 1914 the amount of mineral exported each year corresponded to 7 or 8 grams of radium. At the beginning of 1914 the American Government started measures to monopolize their radium. All the radium mines found in the United States before January 15, 1914, remained the property of their proprietors; but after that all discovered would be the property of the Government. The prospectors had the right of exploiting the mines they discovered but the mineral must be furnished to the American Government at a price which would be fixed from time to time by their Department of the Interior. The American Government established works for the extraction of the precious element. At about the same time the National Radium Institute was founded. It entered into collaboration with the companies established before the decree of 1914, the Standard Chemical Co., the American Radium Co., and the Schlesinger Radium Co., all located at Denver, Colo., or near by.

With a carnotite of meager yield (400 tons yielding 1 gram of radium) but of easy manipulation, the Americans thus became the principal suppliers of radium to the world and monopolized the industry to their profit. This continued until the Belgian Mining Society, Union Minière du Haut Congo, brought to light, in its copper concessions in the Belgian Congo, veins of pitchblende of great richness.

Their first discovery of pitchblende was made in 1913 in the copper mine of Luiswishi. This was followed in 1915 by a second discovery of the mineral in another mine of the same company at Chinkolobwe (Kasolo). Systematic researches undertaken from the beginning of 1921 assisted in locating the uraniferous veins. The first analyses made in the African laboratories of the Union were repeated by M. Schoep, professor in the university at Gand, who at the end of 1921 confirmed the work of the first assays. Because of the richness of the ores, it was decided to transport them to Belgium for treatment. The study of the process for extraction was entrusted to the Société Générale Métallurgique of Hobokens. Under the direction of M. Leeman, with the collaboration of M. Clérin and inspired by the investigations of Curie and Debierne, it perfected the process of reduction of the ore. A factory for the treatment of the Congo mineral was then established at Oolen in the Antwerp Campine.

The work was pushed with such activity that the first cargo of mineral arrived at Antwerp on the 5th of December, 1921. The first part of the plant was in operation the following 8th of July. During that interval of six months the process of extraction had been developed and installed in the new laboratory.

The prospecting continued in 1924 confirmed the existence at Chinkolobwe of considerable quantities of rich mineral yielding up to 60 per cent of uranium oxide. This would be capable of supplying the works at Oolen for a long period. The latter underwent rapid development and produced during 1923 regularly nearly 4 grams of radium per month, assuring thus the supplying of two-thirds of the world's consumption.

When you consider that the American mineral contained scarcely 2 per cent of uranium oxide, and often ore was treated with only three-fourths of 1 per cent, it is not difficult to see that the American mines and works were forced to close. The monopoly, uselessly attempted by the Austrians first, then to a great degree accomplished in the United States of America, has practically wholly passed into the hands of the Belgians. The works all over the world have had to either close or slow up their production, the cost preventing any competition with the Belgian product. Belgian radium can

amply supply the world. Even these laboratories are forced to restrict their production that their reserve of radium may not uselessly augment.

Radium compounds constitute the most expensive bodies of current commerce. The price of radium oscillates about 1,000,000 francs per gram, while platinum reaches 80 francs. M. Chaumet, the well-known jeweler, has told me that a ruby may reach 750,000 francs per gram while a perfect pearl weighing 50 grains would sell for 2,500,000—say 1,000,000 francs per gram.

RADIFEROUS MINERALS

Radium is scattered throughout the rocks of the earth's crust but generally in infinitesimal quantities. Almost all the samples examined by the most sensitive methods show an extremely weak radioactivity; only the pure limestones and the quartz sands are nearly inactive. The waters of springs, mineral waters which have been in contact with radiferous earth, are almost always more or less radioactive. According to direct measures of Strutt, the terrestrial crust contains on the average about 4×10^{-6} grams per meter. The richest rocks are the igneous granites. The sedimentary rocks are much less rich. All radioactive materials are composed of granitic rocks or have been derived from them.

The oldest or primary uraniferous minerals have remained unaltered in the original rocks—like fergussonite, thorianite. By the action of water upon these primary rocks, new minerals have been formed, sometimes within the original beds, sometimes beside them. A great concentration of uranium may thus have resulted. Pitchblende is typical of the secondary rocks. Finally, atmospheric agents, working upon the two preceding classes of minerals, have formed a third more recent class of which chalcolite, autunite, and carnotite are typical.

Pitchblende is essentially an oxide of uranium, U_3O_8, mixed with numerous impurities. The oxide occurs sometimes only as a trace, sometimes in more massive formation. Many elements occur among the impurities. The following table gives the principle components of a rich sample from Joachimstahl:

U_3O_8	75	CaO	5
PbS	5	FeO	3
SO_2	3	MgO	2

The veins of the Belgian Congo have given birth, through the intermediation of atmospheric agents, to a whole new series of compounds recently discovered and studied by Professor Schoep of Gand.

Carnotite is a vanadiate of uranium and potassium, $V_2O_5.2UO_3.K_2O.3H_2O$, of a yellow tint. It is rarely found in a pure state. In the United States carnotite impregnates the old porous sands, giving them a pale yellow tint. The average mineral contains 1.5 to 2.8 per cent of uranium oxide with 3.5 per cent of the anhydrous V_2O_5. These sands extend through immense tracts in the States of Colorado and Utah in beds varying in thickness from ½ to 2 meters or more.

Autunite, $P_2O_5.2UO_3.CaO.8H_2O$, or uranite, has been much exploited in Portugal, in the Province of Beire Baixa. This mineral is prone to mechanical enrichment.

THE EXTRACTION OF RADIUM

To Mme. Curie and M. Debierne we owe the method for the extraction of radium from uraniferous minerals. All the processes since developed utilize in their main lines the methods instituted by these two scientists.

The Austrian Government, whose mine in Joachimstahl has been long worked, extracts the uranium from the pitchblende by a fusion of the pulverized mineral with sodium sulphate. Under such conditions, the sulphate changes the uranium oxide into sodium uranate, easily soluble in dilute sulphuric acid. During the fusion, the radium, if not already in this state, is changed into an insoluble sulphate which remains in the residue. It was these residues, accumulated about the Austrian works, which served, we have already seen, as the first material for the isolation of radium.

We will now state the method used in America in the treatment of carnotite. This method was applied on a very large scale, about 150 grams of radium resulting from the treatment of more than 750,000 tons of the active sand. Then we will indicate the modifications which were necessary for the treatment of pitchblende.

TREATMENT OF THE AMERICAN MINERAL CARNOTITE

The ore arrives at the works in sacks marked with figures which indicate the richness in uranium determined approximately by means of an α-ray electroscope.

The principle of the method of reduction is very simple. The sands impregnated with carnotite are treated with a warm solution of hydrochloric acid which dissolves the carnotite with its elements, vanadium, uranium, and radium. The addition of sulphuric acid precipitates the insoluble barytes, always present, carrying along with them all the radium as radium sulphate. Since the presence of barium is necessary in the subsequent stages of the process, some is added if the mineral itself contains an insufficient quantity.

The insoluble sulphates are first purified and enriched by changing them in an autoclave under pressure into alkaline carbonates; next they are changed into chlorides by solution of these carbonates in hydrochloric acid. These operations are repeated a second time after which the carbonates are rich enough to be passed into the crystallization laboratory. At the time of the solution of the carbonates in hydrochloric acid, a radiferous silica is always precipitated which is given a special treatment for its radium. The carbonates are finally transformed into chlorides. These chlorides, essentially a mixture of the chlorides of barium and radium, are submitted to fractional crystallization.

When a certain richness in radium is reached, it is best to transform the chlorides into bromides; the product undergoes an increase in richness. Moreover, commercially radium is used as the bromide.

The initial hydrochloric liquid containing the vanadium is treated to recover the vanadium. The solution is neutralized by sodium carbonate, then carried to the boiling point, in order to carry the vanadium into a precipitate of vanadic acid containing iron, uranium, etc. All the vanadium is never precipitated. The addition of soda to the liquid just separated from the vanadium precipitates the uranium as the insoluble uranate of sodium, carrying down with the precipitate the greater part of the remaining vanadium. In the United States they go no farther than this first precipitation which gives the oxide of vanadium, since the demand for vanadium is very small.

We will now consider some of the details in the separation of barium and radium. It depends upon the difference in solubility of the two chlorides or the two bromides, those of radium being the less soluble. The operations commence with the chlorides and are finished with the bromides when the concentration of the radium has reached a minimum of 20 milligrams of radium per kilogram of the salt.

The ratio between the concentration in the crystals separated to that of the initial crystals is called the factor of crystallization. The concentration of radium is generally defined by the number of milligrams of radium contained in a gram or a kilogram of the anhydrous crystal.

In the case of the chlorides, the factor of crystallization is 1.6, when the crystals separated represent 50 per cent of the total weight treated. With the bromides the factor is raised to 2.2 with a separation of crystals amounting to 42 per cent of the total.

The following sketch (Barker) shows very clearly the march of crystallization occuring with the chlorides, dividing at each crystallization a half of the salt into two equal parts. At the start a kilo-

gram of the chloride is supposed to be taken containing 100 milligrams of radium.

Each circle represents the composition of a portion before crystallization; the figures above give the weight of the crystals, the figures below the concentration in radium referred to 1 kilogram of the salt. Each figure at the side gives the quantity of radium in the portion.

After the first fractionation, the kilogram of salt is divided into two parts, A and B, each weighing 500 grams and having concentra-

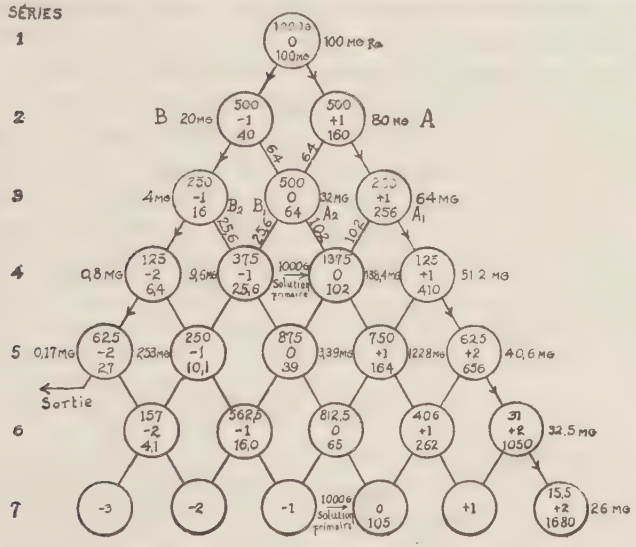


FIG. 1.—The fractional crystallization of radium chloride

tions of 160 and 40, respectively. The portions A and B give further the fractions A_1 A_2 and B_1 B_2 characterized by the following figures:

Portion	Mass	Concentration in radium
	Grams	
A_1	250	256
A_2	250	64
B_1	250	64
B_2	250	16

Note that the portions A_2 and B_1 have the same concentration in radium. The portions are combined so that there remains three parts: A_1 A_2+B_1 B_2.

Similarly the mother liquors from the treatment A_1 are added to the crystals from the treatment of A_2+B_1 while the mother liquors of the last fraction go to the crystals obtained from the fraction B_2.

Thus, though at first the number of fractions keeps on augmenting, there is soon reached a stage of constant fractionation, for it is best to eliminate from time to time the poorest solutions and the richest solutions as indicated in the diagram; for instance, in the fifth series of fractionations there is removed from the series of operations 62.5 grams of crystals in a concentration of 2.7 milligrams. These residues will later reenter into the procedure.

At the fourth fractionation crystals are obtained having practically the concentration of the original salt. We may at this stage profit by introducing a certain quantity of the original salt into the ensemble as indicated in the figure. This artifice has the added advantage of increasing the mass of certain fractionations. At the seventh fractionation this process may be repeated.

We can compute the number of series of fractionations necessary to obtain a given concentration. Let us suppose that we start out with a chloride solution containing in the dry state 0.76 milligrams of radium per kilogram and that we wish to attain a concentration of 20 milligrams of the radium. After a fractionation the concentration of the richer portion is 0.76×1.6; the second series will give for the richer portion $0.76\times(1.6)^2$; after n series we will have $0.76\times(1.6)^n$. Accordingly,

$$0.76\times(1.6)^n=20$$

whence we obtain n equals 7.

It is best now to continue the fractionation after transformation of the chlorides into bromides. If we now wish to attain a concentration of 1 per cent in radium, it will be necessary to make n series of fractions, n being given by the relationship:

$$(2.2)^n=(10{,}000/20)$$

whence n equals 8.

Now let us consider the results of a fractionation starting with 134.25 kilograms of anhydrous chlorides containing 102.8 milligrams of radium and carried to a concentration of 1.1 per cent of radium. We have:

	Milligrams
Radium in the initial chlorides	102.80
Radium eliminated in the chloride fractionation	2.29
Radium eliminated in the bromide fractionation	.47
Radium carried down with the precipitation of lead	1.70
Radium in the final salt at 1.1 per cent	96.04

In order to obtain a like result, it would be necessary in the fractionation of bromide, for example, to take out the rich portion at the eighth crystallization and then to continue the progressive enrichment, with the elimination of the rich fractions so as to condense the greater part of the radium into the enriched quota. This en-

tails as a consequence the retiring during the operations of only a small quantity of the poorer liquids, since only 2.76 milligrams of radium are discarded during the process. From time to time we eliminate by a current of hydrogen sulphide the lead which always exists in small quantities in the solution. As indicated in the above table the resulting sulphide of lead carries down with it some of the radioactive matter.

The table shows the flexibility of the fractionation and how it can be varied to suit the end desired.

The above data comes from Prof. Howard H. Barker, of the University of Missouri, who made very important researches on carnotite. He has pushed the concentration even further. He proposes to conduct the operations so as to have a radium bromide nearly 90 per cent pure. The following table gives some of the data relative to the proposed fractionation:

	Milligrams
Radium in the initial salt 1.1 per cent pure	96.04
Radium obtained as the bromide 88 per cent pure	92.66
Radium obtained as a salt at 1.46 per cent pure	3.51
Radium obtained as a salt at 0.08 per cent pure	.52

96.5 per cent of the radium is accordingly obtained in the form of bromide 88 per cent pure.

All the tubes of radium bromide thus prepared are stored in a room very distant from the physical laboratory. They are examined several times to determine their richness in radium. Generally three determinations of the radium imprisoned in each tube are made by means of the γ-rays: First, soon after the closing of the tube when there is sensibly no emanation; second, four days later corresponding to the time for the growth of one-half the emanation for equilibrium; and finally, about a month later when radioactive equilibrium is practically attained.

The works and the laboratory establish a definite schedule of operations. They keep an accurate account of the amount of radium in the original material, the mineral in the works, the radioactive carbonates for the laboratory and the quantity of radium obtained at the end of the operations, the carbonates for the works and the tubes for the laboratory. From this final result may be judged the efficiency of the various steps.

TREATMENT OF PITCHBLENDE

The industrial treatment of pitchblende residues as carried out by the Austrian Government in the works at Joachimstahl is practically the same as the method first elaborated by Mme. Curie and M. Debierne. The chemists at the works at Oolen, while deriving ideas from the previous process, have conceived for the treatment of the

Congo mineral a method of extraction based upon the same principles as that of Mme. Curie but involving some original ideas in its application.

The dominant impurities in the first Belgian material were copper, iron, lead, phosphoric acid, alumina, and silica. For their elimination at the beginning, the mineral is pulverized and submitted (following M. Leemans) to the four following operations:

1. Attack with acids for the elimination and separation of uranium, iron, copper, and phosphoric acid.

2. Treatment with a sodium chloride solution for the elimination of lead with final precipitation of the metal and the regeneration of the brine.

3. Treatment with hydrochloric acid to eventually eliminate the calcium.

4. Treatment with sodium carbonate to eliminate the sulphuric acid.

At the conclusion of these operations the radium remains in an insoluble form mixed with the silica. This insolubility of radium requires either that it exists at the start as a sulphate in the mineral, which is not very likely, or that it is first changed into the sulphate, for instance, by heating it with sodium sulphate as is done at Joachimstahl. It is then possible to eliminate the impurities by treatment with acids. Hydrochloric acid, 13° Baumé and warm, is particularly recommended for this step. The chloride of lead formed, being only slightly soluble in the hydrochloric acid solution, can doubtless be eliminated by a concentrated solution of sodium chloride solution with which it forms a double salt. The calcium sulphate can be removed with warm hydrochloric acid in which gypsum is quite soluble. Finally treatment with sodium carbonate transforms the sulphates of barium and radium which are insoluble with the silica, into carbonates soluble in hydrochloric acid and they can thus be removed from the silica.

All this earlier part of the process, which entails some 40 operations—filtration, washing, etc.—are carried out in the first building. There results a mixture of impure chlorides of radium and barium in which the radium is mixed with one hundred and twenty-five thousand times its weight of inactive matter. The impurities have been thus reduced one two-hundredth of their original amount. From this point the process is continued as with the carnotites.

In a second phase of the work the chlorides are purified by transforming them several times into sulphates and carbonates, and when the purification has become sufficient the last phase of the process commences: the enrichment of the radium by fractional crystallization at first in the form of chlorides and then as bromides,

The transformation into the chlorides is best made through the help of the carbonates which are finally dissolved in a hydrobromic acid solution.

In the first series of fractionations all the enriched portions are collected as soon as they have reached a quota of 0.05 per cent of radium. The initial solution of chlorides contained only 0.0001 per cent; accordingly, this enrichment is in the ratio to the first state as 125 to 1. This first fractionation takes place in enameled vats, 60 in number, the size of which decreases from the first for the entrance of the material to the last for the enriched crystals.

The work is now continued in the laboratory. Each batch for further purification contains some 2 to 3 grams of radium in a mixture of some 5 to 6 kilos of the mixed chlorides.

During the process of concentration the lead is eliminated from time to time by the passage of a current of hydrogen sulphide. All the operations require the use of very pure distilled water, for the least trace of sulphuric acid, not even detectable with barium chloride, will precipitate the radium as a sulphate less soluble than that of barium. Generally a little barium chloride is added to the water to be distilled to remove the least trace of sulphuric acid.

At the works at Oolen the last fractionation is reached when the radium bromide has become 95 to 96 per cent pure; that is the marketable form of radium.

The crystals thus obtained hold two molecules of water and must be dried to preclude an explosive decomposition of the water. An absolute dessication is obtained by heating the salt up to fusion. It then appears as a whitish mass very luminous in the dark. It is preserved in glass tubes, sealed by melting the glass.

We have noted the important part played during the course of treatment by measures of radioactivity. To avoid the disturbing action of any secondary or parasitic radioactivity the measuring laboratory is situated about a kilometer (0.6 mile) distant from the works.

When the γ-rays alone are desired, the sulphate of radium is preferably used: its greater insolubility giving better guaranty against loss. But if the emanation is desired, a soluble form is necessary, so that it may be easily removed from the emanation.

The following table gives the amount of radium in the principal forms found on the market:

	Per cent
$RaCl_2$	76.1
$RaBr_2$	58.6
$RaBr_2.2H_2O$	53.6
$RaSO_4$	70.2

RADIUM STATISTICS

The mines of Joachimstahl up to 1922 had produced 23 grams of radium. We may estimate that the European total up to the beginning of the Belgian entrance in the field was about 60 grams.

All the previous manufacture of radium was greatly surpassed by the American production which amounted almost to a monopoly. According to Mr. K. L. Kithill, one of the directors of the American works at Denver, there had been taken from carnotite 160 to 165 grams of radium.[2]

Since the Société Minière of Haut Katanga began to put its radium on the market, most of the other works have ceased operations. The great works built by the Americans are idle awaiting the exhaustion of the Belgian minerals before starting up again. We have no information upon the possibility of such a weakening in their production, since the Société Minière of Haut Katanga jealously keeps secret all the results of its prospecting.

However that may be, the works at Oolen, from which the first tube of radium appeared on the market in August, 1922, produced that year 15 grams of radium. During the following year they produced at the rate of 4 grams per month, and therefore up to the end of 1924 had produced 110 grams of radium. However, such a production is ahead of the market demand and they had to slow up or accumulate reserves; in fact, according to the financial journals its sales were limited during 1924 to 22 grams.

From all this, it seems as though we would be near the truth in stating that the amount of radium actually now available, including the Belgian stocks, should be about 300 to 310 grams, having a value of more than 300,000,000 francs.

In 1923 the hospitals and medical institutions of the United States of America owned a total of more than 120 grams of radium; another much smaller quantity was in the hands of the scientists in the universities and scientific institutions. America therefore has more than one-half of the radium available at present.

If we could gather the 300 grams of radium which has been isolated, for the purpose of separating its emanation, we could obtain 20 cubic millimeters, susceptible of giving 31 kilogram calories per hour.

How has the price of radium varied? The following table gives the price in dollars per milligram of the elementary radium since 1904:

[2] These 165 grams have been determined from the amount of radium, sometimes in the anhydrous and sometimes in the hydrated salt, so that the figures should be sensibly reduced as well as all statistics derived from them.

1904	$10 to $25	1912–1914	$180
1905	25 to 50	1915	160
1906	60	1916–1922	120, 110, 105
1909–1910	75 to 135	1923	70
1911–1912	150		

The price of radium therefore rapidly increased from $10 to $160, passing through a maximum of $180. The radium from the American carnotites lowered the price from $160 to $120–$110; it then kept at about $110 until the appearance of the Belgian product upon the market lowered it to $70. Allowing 20 francs to the dollar, radium sells at 1,400 francs per milligram.

The sale of radium requires a complicated organization, since it is necessary to get at a very special clientele—the physicians and hospitals. The producer of radium must educate his clients, support the expense of schools and medical meetings, and seek out new permanent openings. The Americans have created during their ten years of efforts a powerful organization of instruction and propaganda. Further, the Union Minière has concluded with two principal groups of American producers, the Standard Chemical Co. and the Radium Co. of Colorado, a contract which allows it to use to its own profit the American organizations for propaganda for the use of radium. These producers have thus been transformed into commercial agents also.

The Union Minière in lowering the price of radium from $100 to $70 has doubtless thus contributed to the useful applications of radium. It is but just to add in closing that they graciously put 2 grams of radium at the disposal of the Curie Foundation.

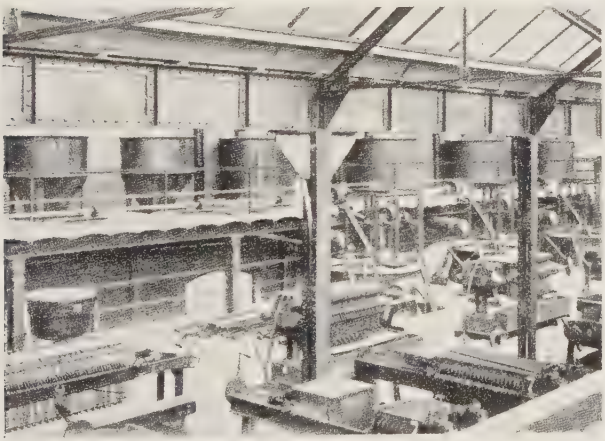
APPLICATIONS OF RADIUM

The only practical application is in its use in therapeutics. I do not wish to penetrate into a domain which is foreign to my experience and will only indicate that the treatment with radium has often given very fortunate results in the treatment of lupus, superficial ulcers, arteriosclerosis, gout, rheumatism, etc. Especially is it used in the fight against cancer.

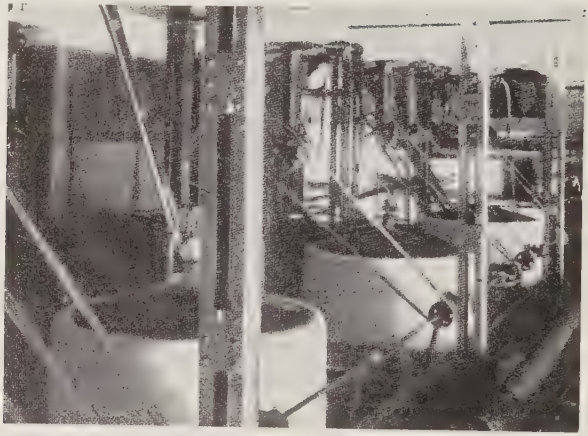
The therapeutic technique of radium is very complicated. Indeed, radium emits radiations which are practically very penetrating X-rays; it projects electrons having very great velocities and endowed with certain penetrating powers and four groups of α-particles characterized each with a particular velocity. These latter particles, which have practically no penetrating power, can act only on the surface of tissues in contact with the radium. We can therefore inject a very dilute solution of an active body into an organ or submit

that organ at each of its parts to the action of all the radium radiations. Each of these radiations evidently can and does have a specific action which is further dependent upon the duration of the action and its intensity. One immediately sees how difficult it is to pick out a particular action so that it may exercise its particular power. We may thus understand the complexity of the problems which are met with in the employment of radium in therapeutics.

1. VATS FOR DISINTEGRATING THE MINERAL, AND FILTERING PRESSES

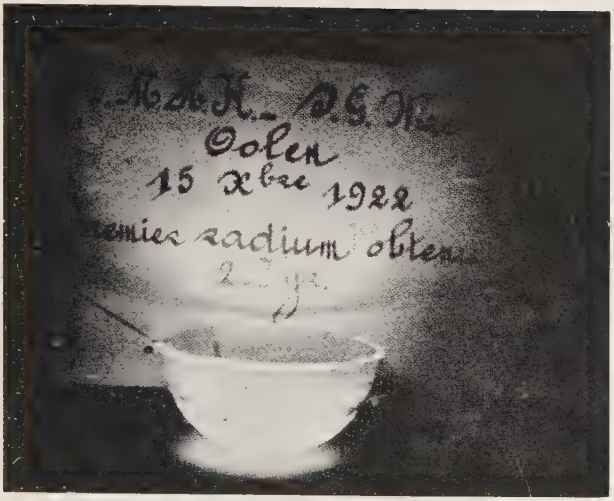


2. VATS AND FILTERS



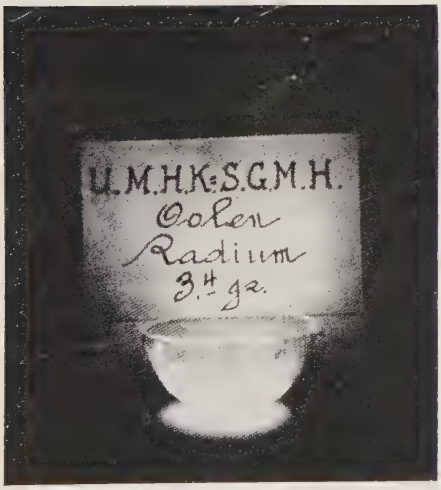
1. VATS AND PUMPS

2. ROOM FOR FRACTIONAL CRYSTALLIZATION



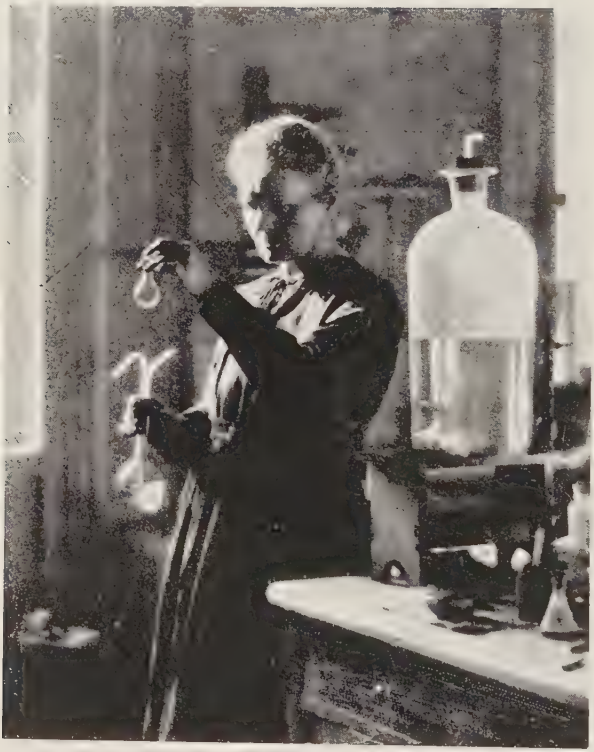
1. CAPSULE OF RADIUM BROMIDE

Photograph made in a dark room by the radiation emitted by radium. Diameter of capsule, 350 mm.



2. CAPSULE OF RADIUM BROMIDE

Photograph made in a dark room by the radiation emitted by radium. Diameter of capsule, 350 mm.



MADAME P. CURIE, PROFESSOR AT THE SORBONNE, IN HER LABORATORY

THE CHEMISTRY OF SOLIDS[1]

By Prof. Cecil H. Desch, F. R. S.

It is remarkable how little we know with any certainty about the chemical properties of solids, although the idea of a solid is so fundamental. At the present time we always begin the study of chemistry with the gases on account of the simplicity of their mathematical treatment, but it must be remembered that this simplicity is the result of long study and of many discoveries. To the unscientific mind the solid is simpler, because more tangible. When men have tried to understand gases, they have expressed themselves in terms of solids. The atom, however attenuated it may have become in recent years, was in the first instance essentially a solid sphere, and the elasticity of gases has been explained in terms of the collision of elastic solid particles in motion.

Our conception of liquids has been based in the same way on the idea of moving particles, themselves thought of in terms of the solid state. Yet, of solids themselves, whilst our knowledge of their physical and mechanical properties is very extensive, our chemical information is of the most meager kind. It was an old doctrine that chemical reactions could only proceed in the gaseous or liquid states, so that chemical action on a solid was always preceded by the tearing off of atoms from the surface under the influence of electrical forces. That view can no longer be maintained. Chemical reactions can occur within or at the surface of a solid, but the experimental difficulties are sometimes such as to make the exact investigation of the subject a difficult matter.

In the modern conception of a solid, the atoms are characterized by a regular arrangement in space, that arrangement being repeated so as to build up a crystalline lattice. Crystals and aggregates of crystals are thus the only true solids, gases being regarded as under-cooled liquids of high viscosity. The X-ray method developed by Laue and by W. H. and W. L. Bragg has made it possible to determine, not only the class of a crystal, but also the exact lat-

[1] From the presidential address delivered at Southampton on Aug. 31 before Section B (Chemistry) of the British Association; reprinted by permission from Nature, No. 2921, vol. 116, Oct. 24, 1925.

tice possible to crystals belonging to that class. The connection between the chemical properties and the crystalline structure still remains indeterminate, although it must be very intimate.

There are many reasons why the chemical study of solids should receive greater attention. In metallurgy, although metals and alloys may, and most frequently do, pass through a molten stage in the course of their manufacture, they may undergo many important changes of structure and constitution at temperatures far below that at which the last liquid portions have completely solidified, and these changes may be so far-reaching as to convert an alloy into one seemingly of an entirely different class, although the gross chemical composition has not altered. The petrologist, especially when dealing with igneous and metamorphic rocks, has to consider reactions which proceed in the midst of solids of high rigidity. Several industries, such as that of cement, are based on reactions of the same kind as those with which the petrologist has to deal. Sintering is not always due to the presence of small quantities of molten material between the solid particles, and it is now certain that union of solid masses under pressure may occur without actual melting. This was shown by Spring 40 years ago, but for long, although frequently quoted, his results received little consideration.

The most striking application of the principle is seen in the metallurgy of tungsten. This metal was formerly described as very hard and brittle, and it is not possible, by casting it and then annealing, to bring it to a ductile form. The method now adopted is to prepare it in the form of a pure powder, and then to bring it to a compact state by compressing, heating, and hammering while very hot, and finally drawing. As this process is continued, and as an originally thick rod becomes extended into a slender wire, the brittleness progressively disappears, and at last the tungsten is obtained in those beautiful filaments, drawn to extreme fineness, with which we are familiar in our electric light bulbs and wireless valves. A somewhat similar example is that of the adhesion of an electrolytically deposited metal to its support, which is sometimes so perfect as to approach the breaking strength of one of the metals, although interpenetration of crystals is not to be seen under the microscope.

There is another aspect of the chemistry of solids which will make an appeal to some who are not chemists, but amateur students of nature. The great beauty of natural crystals has attracted the attention of poets and artists as well as men of science. Much of this beauty depends on the varying habit of one and the same crystal species. Even with such a common mineral as quartz, it is possible on entering a mineral collection to point to some of the crystals exposed, and to name their locality, when once the form has become familiar. The same is true of other minerals. Why should there

be this variation, when the chemical composition of the distinct varieties may be identical, so far as analysis is able to give information?

Again, the crystalline system will not account for the differences in the building up of individuals to form aggregates. Rock salt and cuprite crystallize in cubes, and the space lattice has a very similar form in the two minerals; but when the salt forms multiple growths, the cubes arrange themselves in characteristic stepped pyramids, whilst the red oxide of copper may form the most beautiful hair-like threads, a tissue of scarlet silk, as Ruskin calls it. Neither mineral ever assumes a form which is characteristic of the other, the simple cube being once departed from. Why should this be? It is known that the presence of traces of foreign matter may cause differences of habit, the most famous example being that of the crystallization of common salt in octahedra instead of cubes when a small quantity of urea is added to the solution, but the explanation of these facts is still imperfect.

The work of Johnsen and of Gross has shown that the appearance of a face on a crystal placed in a supersaturated solution is really determined by the velocity of growth in a direction normal to that face, those faces being produced which have a minimum velocity of growth. Some light is thrown on the subject by a study of the growth of a crystal when solvent is completely excluded, the substance used being sublimed in a vacuum. This has been undertaken by Volmer, who finds that cadmium, zinc, and mercury crystals grow in this way in a high vacuum. When small nuclei are present, those grow which have the face with the smallest velocity of growth perpendicular to the stream of impinging molecules. The differences between different faces are large, so that under these conditions either flat tables or long prisms are usually formed, according to the direction of the original nucleus. The crystal grows by the addition of thin laminæ, probably only one molecule thick, which spread over the surface. This is likely to be the process when the crystal is growing in a solution or in a molten mass, as well as in the vapor; and, in fact, when cadmium or tin is being deposited electrolytically at a cathode, or when lead iodide is being formed from a solution of a lead salt and an iodide, the growth of the crystal may be watched under the microscope, when a thin film begins to form at some point on a face, and extends over the face, maintaining a uniform thickness throughout. It is realized that in the presence of a foreign substance, either molecules or ions may attach themselves to such a surface by their residual affinity, and this will necessarily affect the addition of further layers of the original substance. In other words, the velocity of crystallization in a direction normal to that face will be changed. As the residual affinity of different faces of a crystal

must, from the ordinary conception of an atomic space lattice, be different, the habit of the crystal, that is, the relative development of different faces, will be altered by the presence of a foreign substance. It is on these lines that an explanation of differences of habit must be sought.

When a face of a crystal is brought into contact with an etching reagent, such as water for rock salt, hydrofluoric acid for quartz, or cupric ammonium chloride for iron, the surface is not dissolved away evenly, leaving it smooth, but characteristic etching pits are produced, the sides of the pits being evidently crystal faces. This shows that chemical action proceeds more readily along certain planes of a crystal than along others, a fact which we should expect from the general properties of the space lattice. It is not explained, however, why these etching pits should appear at first separate from one another, the intervening portions of the surface being unattacked. Minute particles of some impurity, causing local electrolytic differences, suggest themselves as a possible cause, but it is unlikely that they would be so evenly scattered in, for example, a quartz crystal as to produce the regular distribution which is often observed. Minute inequalities of level, which may be of a periodic character, are more probable, and this suggestion is strengthened by the observation that a polished face of rock salt dissolves evenly in water, whilst a natural cleavage face shows etching pits.

It is now possible, when pursuing the study of solids, to eliminate one of the disturbing factors, the inter-crystalline boundary, by making experiments with specimens composed of a single crystal. There are several ways of preparing single metallic crystals of such a size as to allow of the determination of their physical and mechanical properties. Even so brittle a metal as zinc has an extraordinary ductility in single crystals. The mechanism of deformation has been examined in detail by means of X-rays. There is now a large body of evidence as to the directions of slip in a crystal during deformation, and this knowledge is essential to any understanding of the nature of cohesion, with which the chemical properties are no doubt closely connected.

We may now turn to the subject of chemical reactions which take place in the interior of a solid, either originating at the surface or from nuclei which make a spontaneous appearance in the course of cooling below the melting point. A chemical change which has begun at some point in or at the surface of a homogeneous crystalline mass cannot advance unless the atoms are able in some way to change their places. Gross movements, represented in gases and liquids by convection currents, are out of the question, but the slower process of diffusion, by which atoms or molecules can make their

way through the solid, must be possible. Experiment shows that diffusion in solids, whilst naturally a slow process in comparison with diffusion in liquids, proceeds at quite measurable rates.

The classical example of such measurements, and for many years the only one, is the study of the diffusion of gold in solid lead, undertaken by Roberts-Austen in 1896. A much simpler example is that of silver and gold, two metals which resemble one another closely in chemical character and in atomic volume, so that diffusion causes less change of properties than in any pair of less closely similar metals. The experimental results prove, as might have been anticipated, that diffusion is a much slower process when there is so little difference in chemical character. When the two kinds of atoms are closely alike, the tendency to diffuse must be small, but it is certainly not zero. By making use of an ingenious device, Hevesy has been able to determine the coefficient of self-diffusion of liquid and solid lead. Two isotopes should not differ appreciably in their rates of diffusion, so that when the radioactive isotope thorium B is allowed to diffuse in ordinary lead, the experiment is equivalent to selecting a certain number of lead atoms and attaching labels to them by which they may be identified in the course of their journey. In this way he found that the diffusion in liquid lead near to the melting point was of the order of that of salt in water, but that in the solid state it was very small. Further experiments, using a thin foil, proved that at 2° below the melting point the rate was 1/10,000 of that in molten lead.

When a liquid mixture of two substances which are miscible in the solid as well as in the molten condition, such as an alloy of copper and nickel or a fused mass of albite and anorthite, begins to solidify, the composition of the crystals has to adjust itself continuously in order to maintain equilibrium with the changing liquid phase, as was shown by Roozeboom in his classical work on solid solutions. Such an adjustment is only possible by means of diffusion, and when cooling is sufficiently slow, the adjustment does in fact keep pace with the change in the liquid, but with more rapid cooling the interior of each crystal differs in composition from its outer layers, there being a concentration gradient from the center to the boundary. This condition produces the "cored" crystals which are familiar to every metallurgist, and the "zoned" crystals of the mineralogist. In most alloys this want of homogeneity disappears after a sufficiently long period of heating at some temperature below that at which the first drops of liquid are formed, but alloys of bismuth and antimony fail to become uniform even after weeks of annealing, whilst the felspars and similar minerals have never been persuaded to lose their zoned structure by any methods known in the laboratory.

Bruni has shown and Vegard has confirmed the observation by the X-ray method, that true interdiffusion occurs between potassium and sodium chlorides when mixed and heated in the solid state. Electrolytic transport is observed in the solid halides of silver and in mixtures of silver and copper sulphides, but the modern view of the structure of such substances represents them as built up of ions rather than of neutral atoms, and this must be taken into account in any interpretation of the facts. The apparent absence of diffusion in minerals which have once solidified, even when given geological periods of time, is a serious difficulty in the way of any general theory of diffusion. Such examples of the passage of alkali metals through quartz and other silicious minerals under the influence of a difference of electric potential are probably not examples of true diffusion at all, but merely of the passage of traces of impurities through a mass which is not completely impervious.

A new field of investigation has been opened up by Tammann in his attempts to determine the arrangement of the atoms in solid solutions by purely chemical means, by studying the action of chemical reagents on the solid. It is a familiar fact that the "parting" of silver and gold in assaying, which consists in dissolving out the silver from the alloy by means of nitric or sulphuric acid, is only possible when the silver forms more than 60 per cent of the alloy. When gold is present in excess of this proportion, only a little silver is removed from the surface, and the action then comes to a standstill, the acid being unable to penetrate to the interior. Assuming the alloy to be completely crystalline, the atoms of silver and gold will occupy the points of the space lattice, and as the two metals have face-centered lattices of only slightly differing dimensions, the amount of distortion will be small. There are, however, different ways of arranging the two kinds of atoms. They may be distributed at random, or they may be so regularly arranged as to form two interpenetrating cubic lattices.

The two forms of distribution may be distinguished by means of the X rays, but Tammann has also drawn conclusions on the point from the action of various reagents on the alloys. He finds that each reagent which attacks silver ceases to act on the alloys when the proportion of gold atoms in solution exceeds a certain limit, which is not the same for different reagents, but he states that it is always capable of being expressed as one-eighth, two-eighths, three-eighths, and so on, of the total number of atoms. The limits so found are not consistent with the distribution according to the laws of probability, but they may be accounted for by a regular distribution on the assumption that a certain number of inactive atoms is necessary to protect each atom of silver.

On the basis of these results, an ingenious theory of the action of reagents on solid solutions has been constructed, and although the accuracy of the experimentally determined limits is not high, and there are several exceptions to the rules, an interesting case has been made out.

If our knowledge of the chemical properties of the interior of a crystal be very incomplete, what are we to say of its surface? Of this we know still less. Even in a crystal of a pure metal there must be some difference in the structure at the immediate surface, on account of the unsymmetrical forces between the atoms in the outermost layer and its neighbors. For so far as the radius of sensible atomic forces extends, therefore, there must be a condition different from that which prevails at a depth below the surface. One consequence is that the surface has residual affinity, which shows itself in the ease with which foreign atoms or ions will attach themselves to it. That the forces acting are chemical is shown by the great effect on the extent of adsorption of the chemical character of the solid and of the adsorbed substance. Films, often one atom thick, attach themselves to the solid, and are only removed with the greatest difficulty. Their presence makes the investigation of the properties of a surface difficult, as the surface actually examined may be in reality quite different from that which is assumed to be present. In photochemical experiments with mercury it is usual to prepare a completely fresh surface of the liquid metal by causing it to flow continuously in a fountain, but this device can not be applied to solids. Only rarely can experiments be made with perfectly defined solid surfaces. Films of metal prepared by sublimation or sputtering in a vacuum are probably the most under control, but other surfaces are commonly covered by invisible films.

Schumacher has recently shown that mercury wets glass and silica more and more readily as care is taken to remove films from them, and the property of not being wetted by mercury is probably not one of glass and silica, but of those substances coated with a film of gas. Metals most readily take up atoms of oxygen or other elements, forming persistent films, which play an important part in the phenomena of resistance to corrosion.

There is one way of preparing a fresh surface of a crystalline solid for examination, and that is by cleavage. A freshly cleaved plate of a mineral may be supposed to be clean at the moment of its formation, although it will rapidly take up foreign atoms from the surrounding gas. Tammann has made the interesting observation that a fresh surface of mica is more soluble in water than an older one. Washing with water immediately after cleaving extracts a quantity of alkali salts which is much above the normal solubility of mica, and later washings extract only the normal quantity. It is sug-

gested that the separation of the flakes of mica exposes the alkaline part of the molecules, which would be more readily attacked by water than the siliceous part. It will be interesting to see whether the X-ray examination of mica confirms this arrangement. Again, however, a word of warning as to the effect of possible impurities must be uttered. Natural minerals are not pure, and any uncombined alkaline salts present might well segregate along cleavage planes in the process of crystallization, and so give rise to the effect noticed above, but the figures recorded by Tammann are striking and suggestive.

In this hurried review of a large field it may seem that I have presented rather our ignorance than our knowledge, my intention having been to show how much remains to be done before we can understand the chemical relations of solids as we do those of liquids and gases. One department of research is, however, more advanced than might have been supposed from my brief references to it. That is the study of the internal changes in metallic alloys as revealed by the microscope and by thermal and electrical methods Metallography has made wonderful progress since the days of Sorby, and it would repay students of physical chemistry to give some attention to its main results, even though they may not intend to make a special study of the subject. Nowhere are the benefits of the doctrine of phases of Willard Gibbs to be more clearly traced, whilst the recognition of every change of phase by microscopical examination, making use of a technique which has been brought to a high state of perfection, gives concrete reality to the study by direct verification of its conclusions.

To understand more thoroughly the mechanism of these changes in alloys and to extend its application to salts, minerals, and rocks, we need a fuller knowledge of the relation between crystal structure and chemical behavior. Research on the mechanical side is discovering the direction of planes of slip in the atomic space lattice under stress, and it remains to determine the corresponding planes of greatest and least chemical activity towards a given reagent. Next follows the still unsolved query as to the nature of the intercrystalline boundary, and the solution of these two problems will make it possible to define exactly the chemical character of a given aggregate of crystals. The results will be of extreme interest for the study of metallurgy, of mineralogy, and of petrology, besides filling a serious gap in chemistry, serious because of the extent to which solids compose the world around us, and of the part which they play in our daily life.

TERRESTRIAL MAGNETISM IN THE TWENTIETH CENTURY[1]

By Daniel L. Hazard
Coast and Geodetic Survey

One of the early presidents of the American Association for the Advancement of Science in his presidential address likened himself to a biennial plant, which for the first year devotes itself to storing up a reserve supply of plant food and in the second year bursts into flower. The character of the flower is an indication of the adequacy of the stored food supply. The president of this society is in much the same category.

The close of the nineteenth century witnessed a marked quickening of interest in the study of the earth's magnetism, of which one evidence was the expansion of the magnetic work of the United States Coast and Geodetic Survey, the establishment of a separate division of terrestrial magnetism, and the inauguration of a magnetic survey of the United States.

Now, after the lapse of a quarter of a century, it will not be amiss to take account of stock and see to what extent our knowledge has been increased and how far we have advanced toward the solution of the perplexing problems of the causes of the earth's magnetism and its variations.

It must be borne in mind that the science of terrestrial magnetism is comparatively young. Although Gilbert in 1600 conceived the idea of the earth as a great magnet, similar to a spherical lodestone, he had almost no observational data with which to test his theory, and it was not until 1838 that a fairly correct idea of the nature of the earth's magnetism and its distribution was developed by Gauss from his analysis of the results at that time available. With the character of the phenomenon established, the natural philosophers were quick to realize the importance of observations more widely distributed over the earth as a prerequisite for a more effective study.

[1] Address of the retiring president of the Philosophical Society of Washington, presented at the meeting on Jan. 10, 1925. Reprinted by permission from the Journal of the Washington Academy of Sciences, vol. 15, No. 6, Mar. 19, 1925.

On the initiative of Humboldt and Gauss, supported by Herschell, Kupffer, and Sabine, there was developed one of the earliest cases of international cooperation for the study of a world-wide phenomenon, which was remarkably successful when the conditions of transportation and communication at that time are considered. Magnetic surveys were undertaken, observers were sent to regions where magnetic observations had not previously been made, including the expedition of Ross to the vicinity of the magnetic south pole, and magnetic observatories were established about 1840, at widely separated points, for the study of the variations of the earth's magnetism. In spite of the imperfect instruments then available, the operation of these observatories served to establish the principal features of the short period variations of the earth's magnetism. Some of them were discontinued at the close of the limited period for which international cooperation had been arranged, but others continued in operation much longer, some (as the one at Toronto, Canada) even to the present day. It is of interest to recall that, thanks to the zeal of A. D. Bache, later Superintendent of the Coast Survey, a magnetic observatory was operated at Girard College, Philadelphia, from 1841 to 1845, and that variation observations were made in this city from 1840 to 1842. One of the observatories established by Russia was at Sitka, Alaska, and was in operation from 1842 to 1867. The results obtained brought out the fact that the variations of the earth's magnetism are different in different magnetic latitudes and called attention to the probability of some relationship between the presence of sun spots and the occurrence of auroras and magnetic storms on the earth. The desire for more information regarding the connection between these two terrestrial phenomena led to further international cooperation in the establishment of a ring of temporary magnetic observatories around the borders of the Arctic Ocean to be operated for three years from 1882.

From that time on the interest in the study of the earth's magnetism steadily increased, not only in the extension of magnetic surveys and in the operation of additional magnetic observatories, but also in the discussion of the results and investigations regarding the cause of the phenomenon.

In most countries the magnetic observatories were established as an adjunct to existing meteorological observatories and given a subordinate position. At the meeting of the International Meteorological Conference held in Paris in 1896, however, recognition was given to the growing importance of the science of terrestrial magnetism by the appointment of a Permanent Commission for Terrestrial Magnetism and Atmospheric Electricity.

A fresh impulse was given to the growth of interest by the appearance in 1896 of the Journal of Terrestrial Magnetism edited by

Bauer, with the cooperation of most of the leading magneticians of the world. This provided a medium for the interchange of ideas and a forum for the discussion of problems of international import of much greater value than the triennial meetings of the international commission and helped to prepare the way for more ready acquiesence in recommendations of the Commission requiring international cooperation or agreement.

The investigations of the nineteenth century had shown that definite conclusions regarding the causes of the earth's magnetism and its variations could not be reached until more accurate, more detailed, and more widely distributed observations had been made, and the first quarter of the twentieth century has been characterized by almost world-wide activity in the accumulation of observational data. More or less detailed magnetic surveys have been made by nearly every civilized country, new magnetic observatories have been established, instruments and methods of observing have been improved, greater homogeneity of results has been secured by national and international comparisons of instruments, and a fuller and more prompt publication of results has been the rule.

In this accumulation of data the United States has played a most important part, and that it has done so is largely the result of the energy and persistence of Dr. Louis A. Bauer. His efforts in 1899, backed by those of Dr. Henry S. Pritchett, at that time superintendent of the Coast and Geodetic Survey, resulted in the appropriation of funds necessary for the expansion of the magnetic work of that bureau, so that it became possible to make a general magnetic survey of the country, including the islands under its jurisdiction and parts of Alaska, and to establish and operate five widely separated magnetic observatories. This work was planned and the magnetic survey carried well toward completion under his direction.

Designed primarily to meet the practical needs of the navigator and surveyor, this survey at the same time supplied the data needed for the study of the problems of the earth's magnetism.

Realizing that only a small portion of the earth's surface is occupied by the civilized nations and that it would be extremely difficult to secure governmental funds for work to be done outside a country's jurisdiction, Bauer presented to the trustees of the Carnegie Institution of Washington a plan for the establishment of a bureau for international magnetic research, including a world magnetic survey to supplement the work being done by other agencies. This plan was approved, and the Department of Terrestrial Magnetism of the Carnegie Institution of Washington was established in April, 1904.

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While in charge of the magnetic work of the Coast and Geodetic Survey, Bauer had satisfied himself of the feasibility of making magnetic observations at sea with nearly the same accuracy as on land, if a suitable vessel could be obtained. His plan for the world survey, therefore, included provision for a magnetic survey of the ocean areas by means of a non-magnetic vessel. This work at sea was carried on successfully from 1905 to 1921, first on the *Galilee*, a chartered sailing vessel, and later on the *Carnegie*, a sailing vessel with auxiliary power, built for the purpose so nearly free of magnetic material as to practically eliminate the need of taking account of deviation corrections.

While this work at sea was carried on primarily for scientific purposes, it had great immediate practical value in that it provided the means for correcting the existing world isogonic charts, which were found to be seriously in error because of the insufficient data on which they were based.

At the same time magnetic observers were sent to nearly all accessible regions where magnetic surveys were not being made under other auspices and to some regions usually thought of as inaccessible. Asia, Africa, South America, Central America, Mexico, were all the field of these far-reaching operations. In some instances, as in Canada, one season's work by an observer of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington was sufficient to stimulate local interest to a point where means were provided for continuing the work under local auspices. Advantage was taken of these world-wide travels to secure comparisons of instruments with the standards of the various magnetic observatories and other agencies engaged in making magnetic surveys, thus insuring a greater homogeneity of results, in some cases calling attention to defective instruments and in general emphasizing the importance of better instruments and methods.

Some idea of the magnitude of the work done in this world magnetic survey may be gained from the statement that it covered all the ocean areas from latitude 70° north to 60° south, nearly all of the land areas from 30° north to 60° south, excepting India and the Dutch East Indies, and in addition parts of China, Persia, and Canada.

During the same period governmental magnetic surveys have been made in India, New Zealand, Dutch East Indies, South Africa, Canada, and Russia (including Siberia), and resurveys have been made of Japan and the British Islands, and in France, Prussia, and other European countries. Thus it will be seen that during the past 25 years there has been executed a world magnetic survey

covering practically the whole surface of the earth between latitude 70° north and 60° south.

At the same time the making of magnetic observations has been recognized as an important part of the work of an exploring expedition, and as a result much information has been obtained regarding conditions in regions which would not ordinarily be reached. This is particularly true of the polar regions. The Ziegler expedition to Teplitz Bay, in 1903 and 1904, Amundsen's work in the vicinity of the magnetic North Pole, 1903–1906, and along the north coast of Siberia in 1918–1921, and the work of MacMillan's two expeditions served to reduce materially the size of the magnetically unexplored region around the North Pole, while the various South Polar expeditions, German, French, British, and Australasian, between 1902 and 1912, supplied a large amount of valuable information regarding magnetic conditions on the borders of the Antarctic Continent, and served to locate the position of the south magnetic pole within narrow limits. The operation of temporary magnetic observatories by some of the expeditions made possible a comparison of the magnetic variations in polar regions with those in lower latitudes, the value of the comparison being enhanced by cooperation at a number of leading observatories in the form of a more open time scale on the magnetograms at specified times.

While there were plenty of magnetic observatories in operation 25 years ago, their distribution was very unsatisfactory. Out of about 40 making reports, 70 per cent were in Europe; there was only one in North America (Toronto), none in South America, and only four in the Southern Hemisphere. With the new observatories established since that time there has been a great improvement in the geographical distribution, so that more than 50 per cent of the present active observatories are outside of Europe and 10 are in the Southern Hemisphere. Here again the United States has taken a leading part. Observatories have been operated by the Coast and Geodetic Survey at Cheltenham, Md.; Tucson, Ariz.; Vieques, P. R.; Sitka, Alaska; and near Honolulu, Hawaii, and by the Department of Terrestrial Magnetism at Watheroo, Australia, and Huancayo, Peru. Other new observatories at Cordova and New Year Island, Argentina; Vassouras, Brazil; Apia, Samoa; Christ Church, New Zealand; Dehra Dun, India; Helwan, Egypt; Sodankyla, Finland, and Meanook, Canada, have all helped to extend the area covered. At the same time some of the older observatories have been discontinued, and others have been compelled to move to new sites, because of the encroachment of electric car lines and other industrial developments.

Improved methods and instruments have added materially to the accuracy of the results. In the development of new and improved

field instruments the Department of Terrestrial Magnetism has been particularly active, to meet the very varied conditions under which it has had to operate, especially in the matter of observations at sea. The design of a portable galvanometer, for use with the earth inductor, has made it possible to use that instrument in the field in place of the dip circle, and the addition of a special device for rotating the coil of the earth inductor adapted it for use on board ship. The marine collimator permits more accurate declination observations at sea, and the sea deflector provides a method of determining directly the horizontal intensity on board ship. Magnetometers have been improved to secure greater ease of handling, adjustment and transportation, and various combination instruments have been devised for use where a very light, compact outfit is essential.

The sine galvanometer, of which three types have been developed, provides an electrical method for determining the horizontal intensity, combining rapidity with great accuracy. It is particularly well adapted for a standard instrument, and in Japan it has been used successfully in the field.

The variometers designed by Eschenhagen, with very small magnets, have permitted the erection of smaller observator buildings for the variation instruments and a decrease in the cost of operation, since it is possible to have three variometers record on a single photographic sheet. More complete control of the instrumental constants is also provided.

With so much energy being devoted to the collection of observational data, it would not be surprising to find a falling off in the attention paid to the discussion of results; but this has been true only to the extent that the utilization of the data has not kept pace with its accumulation. There has been no falling off in the zeal with which magneticians have attacked the problems awaiting solution. Many of those who had taken a prominent part in the investigations of the last half of the nineteenth century have gone one by one, leaving their places to be filled by a younger generation. Schott, Eschenhagen, Wild, von Bezold, Snellen, Börgen, Sutherland, Fritsche, Bidlingmaier, Neumayer, Rücker, Birkeland, and Leyst are among those whose names will always be recalled when reviewing the progress during that period.

The fundamental problem of the cause of the earth's magnetism and its variations, attacked from many sides and with various weapons, has thus far withstood the attack. One theory after another has been advanced only to be withdrawn before the irresistible assault of observed facts. Some theories fitted well enough qualitatively, but were entirely inadequate when quantity was taken into

account, while others which seemed plausible at one stage of our knowledge had to be discarded when our knowledge increased.

Advances in other fields of science have been seized upon in the hope that they might furnish a clue to the mystery of the earth's magnetism. Cathode rays, the electronic theory of matter, the constitution of the sun, and the probable condition of the interior of the earth are all being studied as to their possible bearing on the magnetic field of the earth.

Gilbert's conception of the earth as a great magnet uniformly magnetized about its axis of rotation, and subsequent modifications, had to be discarded with the acceptance of a very high temperature for the interior of the earth and the recognition of the demagnetizing effect of heat, coupled with the small amount of magnetic material found in the visible rocks. At the same time the magnitude of the anomalies (the departures from a uniform magnetization) indicated the presence of large masses of magnetic material not far from the surface. Recent investigations in various fields have suggested the possibility that some of the properties of matter subjected to very great pressure may be materially different from those observed in the laboratory at ordinary pressures. Susceptibility to magnetization may be one of those properties, and the Department of Terrestrial Magnetism, with the cooperation of the Geophysical Laboratory of the Carnegie Institution of Washington, is arranging a series of experiments designed to test the matter.

Nippoldt, in 1921, returned to the idea of the earth as a magnetized sphere, because of the difficulty of providing a satisfactory system of electric currents to account for the observed magnetic field. He advanced the theory that the principal part of the earth's magnetic field consists of a nonhomogeneous magnetization of the earth's crust down to a depth of about 20 kilometers. In addition, there may exist for the earth's nucleus a magnetic field symmetrical both about the axis of rotation and about the equatorial plane which may have arisen in the same manner as the general magnetic field of the sun. He assumed that the proportion of magnetite in the earth's crust increases with depth below the surface, but that the distribution is not homogeneous. He also assumed an inner core composed of iron, nickel, and cobalt, as suggested by geophysicists, with the possibility that it may be susceptible of magnetization in spite of the high temperature, in view of the magnetic effects observed on the sun by Hale.

Adolph Schmidt points out that even on the assumption that at a depth of 20 kilometers the earth's crust is composed entirely of magnetite, the average susceptibility would not be great enough to account for the observed conditions at the surface.

When it became apparent that the conception of the earth as a permanent magnet could not be sustained, the idea was advanced that the earth's magnetic field might be due to electric currents flowing about the earth, either below the surface or in the atmosphere—the earth an electro-magnet. The mathematical analysis of the earth's field according to the method devised by Gauss and extended by Neumayer and Petersen (1891), and Schmidt (1896), indicated that a small portion of the earth's magnetism, perhaps one-fortieth, could be referred to forces outside th eearth, another small portion to vertical electric currents, but by far the larger part to a system of forces within the earth. A new analysis made by Bauer in 1922, using improved data based on modern observations, gave approximately the same result. He reached the conclusion that for a satisfactory representation of the observed data it is necessary to recognize the existence of an internal magnetic system constituting about 94 per cent of the total field, and an external system and a non-potential system about equal to each other in amount.

A comparison of his results with those previously obtained for the epochs 1842 and 1885 indicated that the intensity of magnetization of the earth had been decreasing during the 80-year period at an average annual rate of 1 part in 1,500, a rate of loss which it is hard to reconcile with the age of the earth and the present intensity of magnetization unless we suppose that there have also been periods of increasing intensity.

Bauer also carried out the harmonic analysis separately for parallels of latitude at 5° intervals from 60° south to 60° north and found an apparent correlation between distribution of land and water and intensity of magnetization, the intensity being greater for the parallels falling largely on the land.

In an earlier (1911) discussion of the earth as an electromagnet, Bauer took the position that the system of magnetic forces within the earth required by the Gaussian analysis might be the result of magnetizing currents outside the earth, namely, negative electric currents circulating from west to east, but he later withdrew this hypothesis, after further study of the problem. As it seems to be established that the diurnal variations of the earth's field and the disturbances must be ascribed to outside currents, it would be much simpler to account for those changes if the field itself is due principally to outside currents.

The idea of the earth as an electro-magnet naturally suggests the possibility that its magnetism may be caused by its rotation. This possibility has been the subject of much study, particularly by Barnett, who has shown experimentally that a piece of iron may be magnetized by rotation; but the observed effect was much too small to account for the earth's magnetism. Swann attacked the problem

mathematically and concluded that any effect due to rotation would be too small to be detected. In 1900 Sutherland suggested as a possible cause of the earth's magnetism the rotation of an electrostatic field within the earth (a positively charged core and a negatively charged crust, or vice versa), as Rowland's experiments had proved that a moving charge of electricity produces a magnetic field analogous to that of a current, but this theory proved untenable when submitted to analysis.

The development of the electronic theory of matter with the atoms consisting of a positively charged nucleus surrounded by negatively charged electrons led Sutherland to suggest that if for some unknown reason connected with gravitation the negative charge of the atom was further from the center of the earth than the positive charge by only 0.4×10^{-8} cm., it would account for a magnetic field comparable with that of the earth. Here again, when the theory was submitted to analysis and the electronic theory was more fully developed, it was seen that Sutherland's hypothesis was untenable either qualitatively or quantitatively.

Failing to find a satisfactory explanation of the earth's magnetism on the basis of the known properties of matter and the accepted laws of electrodynamics, J. J. Thomson, Sutherland, Bauer, and Swann have suggested that we may have to look for some slight but fundamental modification of those accepted laws, possibly as regards the mutual attraction and repulsion of moving positive and negative electrons, similar to a suggestion by H. A. Lorenz regarding the cause of gravitation. Indeed there seems to be growing a belief that gravitation and terrestrial magnetism are very closely allied and probably to be traced to a common origin.

Realizing the difficulties in the way of a direct attack on the problem, especially before more complete observational data were available, many magneticians have turned their attention to a study of the variations of the earth's magnetism and their correlation with associated phenomena, such as atmospheric electricity, earth currents, auroras, sun spots, solar radiation, meteorological phenomena, hoping in this way to throw light on the main problem. In particular, magnetic storms, those irregular disturbances of large amplitude and comparatively short duration, have been the subject of much study.

From the time of the earliest comparisons of photographic records from widely separated observatories, it was recognized that the more severe magnetic disturbances occur at practically the same time all over the earth, and further comparative study of abrupt beginnings and sharp turning points indicated strict simultaneity, the departures therefrom being ascribed to errors inherent in the time measurements, so that more accurate determination of the time of occurrence of such salient features was suggested as a method of determining

differences of longitude. In fact, van Bemmelen, from the mean of 53 abrupt beginnings, computed the difference of longitude between Batavia, Java, and Greenwich, and obtained a value differing by only 9 seconds from the one derived in the usual way.

On May 8, 1902, there occurred a magnetic storm, the abrupt beginning of which coincided with the eruption of Mont Pelée, as nearly as the time of that disastrous outbreak could be determined. This apparent coincidence suggested the possibility that the two phenomena might be related. Bauer made a study of this storm in 1910, based on the records of 25 observatories, and reached the conclusion that it did not begin at the same instant all over the earth, but on the contrary had its origin in about longitude 75° west of Greenwich and traveled eastwardly around the earth, requiring between three and four minutes to complete the circuit. A similar study of another storm of distinctive features supported this conclusion.

For further evidence on this very important question, Faris made a study of 15 abruptly beginning storms occurring in 1906–1909, using the records of the five magnetic observatories of the Coast and Geodetic Survey, and his results apparently confirmed Bauer's conclusions, the transmission time again coming out about 3½ minutes. It was necessary, however, to assume that some of the storms traveled from west to east, as had been suggested by Bauer. Faris pointed out that probably the greater part of the error of determining the time of an abrupt beginning is due to the difficulty of selecting the exact point of beginning on the curve. Bauer accordingly secured reports from 23 observatories on the same storms which Faris had investigated, making an effort to secure more homogeneous data by means of tracings of portions of the curves showing the points selected for measurement. A discussion of these more accurate data failed to confirm the conclusions drawn from the earlier investigations. Rodés also made a study of a number of abrupt-beginning storms between 1910 and 1921, and found no evidence of storm propagation of the character suggested by Bauer, but he did find some indications that a terrestrial magnetic storm may begin at the "front meridian," that portion of the earth, that is, which would be the first to meet a stream of electrified particles coming from the sun, occurring later on both sides of that meridian.

The close correlation between the occurrence of magnetic storms and auroras and the presence of large spots on the sun naturally led to attempts to trace a causal relationship. It was soon seen that a direct magnetic effect by the sun was out of the question. With the development of the idea of currents of electricity being the cause of the earth's magnetism, different forms of electric discharge emanating from the sun were successively put forth as the cause of the observed terrestrial phenomena, the theories advanced keeping pace

with the development of our knowledge of electrical discharges in a vacuum.

Birkeland, Arrhenius, and Nordmann agreed in considering the auroral rays as a luminescence produced by the absorption of cathode rays in the upper atmosphere, and attracted toward the earth's magnetic poles. Birkeland, who devoted many years to the study of auroras, first supposed that the cathode rays were emitted directly from the sun, but later he advanced the modified theory that cathode rays from the sun set up electric currents in the atmosphere which in turn emit secondary cathode rays. He supported his theory by the production of artificial auroras in the laboratory, about a magnetized steel ball in a tube of rarefied air exposed to cathode rays.

Paulsen in 1906, after calling attention to the difficulties with earlier theories, sought to explain the aurora and magnetic storms by a strong ionization of the upper layers of the atmosphere above the zone of maximum frequency of the aurora.

Störmer, who had worked with Birkeland in both his observational and experimental studies of the aurora, knowing that the phenomenon of the concentration of cathode rays toward a single magnetic pole had been mathematically treated by Poincaré, thought it might be worth while to determine mathematically the trajectories of electric corpuscles coming from the sun into the magnetic field of the earth, hoping to bring out the principal features of the aurora. These studies began in 1903 and covered a period of about ten years. Störmer simplified the problem at the outset by treating the earth as a spherical magnet, and neglecting the relative motion of the earth and sun, and then modified the results obtained for this simple case to correspond to the more complex conditions actually existing. In this way he was able to develop paths for the corpuscles which seemed to fit the general features of the aurora as it appears in nature and of the artificial aurora of Birkeland, and thus tended to strengthen the corpuscular theory of its origin.

The correlation of magnetic storms with sun spots, although very satisfactory when based on yearly averages, leaves much to be desired when individual cases are considered. Thus, severe magnetic storms sometimes occur when no large sun spots are visible and, on the other hand, the appearance of a sun spot is not always accompanied by a magnetic storm. To account for this, Maunder advanced the theory that the solar activity which gives rise to magnetic disturbances on the earth does not act equally in all directions but along narrow well-defined streams, not necessarily truly radial; that these streams arise from active areas of limited extent; that these active areas are not only the source of our magnetic disturbances but are also the seats of the formation of sun spots; that these areas can be active both before a spot has formed and after it has disappeared. The fact that

large magnetic storms frequently follow each other at an interval approximating the time of revolution of the sun and that such recurrence has been traced for several rotation periods, not every recurrence being accompanied by a visible sun spot, requires some such explanation as that suggested by Maunder.

Chapman, after a detailed analysis of a number of magnetic storms, attempted to show how some of their characteristics may be produced by streams of electric particles entering the atmosphere from the sun, but this theory, like so many others, failed to fit all the facts.

The researches of Hale at the Mount Wilson Solar Observatory on the evidence of magnetic polarity in the sun spots occurring in pairs and on the general magnetic field of the sun have further stimulated the efforts to trace a connection between solar and terrestrial magnetism and opened the way for a study of the details of the sun's magnetic field. According to the most recent analysis by Seares, the sun's magnetic axis makes an angle of about 6° with the axis of rotation.

When we consider the diurnal variation of the earth's magnetism a different problem is presented. Here we have to deal with a phenomenon which is a function of local mean time, as contrasted with magnetic storms, which, as we have seen, occur everywhere at practically the same absolute time. Attempts have been made to correlate the diurnal variation with changes of pressure, temperature, humidity, and other terrestrial phenomena which have a period the same as the earth's rotation, but without success. Broadly speaking the diurnal variation is a function of the position of the sun above the horizon, distinctly a local phenomenon. The extremes and the principal portion of the variation occur during the daytime. During the night hours there is comparatively little variation. In view of this fact, it occurred to Bauer that the interposition of the moon between the earth and the sun at the time of a solar eclipse might have an appreciable effect on the earth's magnetism. Accordingly he arranged for special observations by observers of the Coast and Geodetic Survey at the time of the total eclipse of May 28, 1900, at stations extending from Alabama to Maryland. The results indicated a small but definite disturbance associated with the passage of the moon's shadow across the place of observation and of the character to be expected. Similar observations have been made at all accessible solar eclipses since that time, principally on the initiative of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, but with the cooperation of other observers in the countries crossed by or contiguous to the belt of totality. These have in general confirmed the results of the first series, though the effect produced by an eclipse

is so small that it can not be definitely recognized when ordinary magnetic disturbances are in progress.

Much study has been given by Chree, Chapman, and others to the details of the diurnal variation, particularly to a comparison between conditions on quiet days and disturbed days and between conditions in high and low magnetic latitudes. Material has been provided for a more accurate study of those features which are not purely local, such as the effect of change of geographic position on the form and amplitude of the curves, through the publication by many observatories of diurnal variation tables based on five internationally selected quiet days, thus eliminating to a large extent the lack of homogeneity which magnetic disturbances might introduce.

Still another problem is presented by the secular change of the earth's magnetism, which requires centuries for its development. Time enough has not yet elapsed since the beginning of measurements of the earth's magnetism to fully determine the characteristics of this change, but we do know that it does not go on indefinitely in one direction; eventually there is a reversal.

In the case of declination, the records at some European stations go back far enough to show two reversals, with a range, in the case of London, of 35° in a little over 200 years. This suggested the idea of periodicity and a motion of the magnetic pole as the cause of the secular change, as it seemed possible to follow the occurrence of a particular phase from east to west around the earth.

Data accumulated during the past 25 years show that the phenomenon is very complex. The change is by no means regular; the periods indicated for different stations differ widely; unexpected reversals occur and there are undoubtedly waves of shorter period superimposed upon the primary wave, if indeed there is a primary wave. It is impossible to predict with accuracy what conditions will be 10 years from now.

Bauer has made a mathematical analysis of the secular change of the earth's field as a whole, and has concluded that the system of forces involved is partly within the earth and partly outside and that the strength of the field is changing as well as its direction. It is not easy to conceive of a system of forces acting for a long term of years to produce such a great change in the direction of the earth's magnetic field. A loss of magnetism would not be surprising from our experience with artificial magnets, but such a rapid loss as one part in 1,500 per year for 80 years or more requires verification on the basis of more accurate secular change data for the whole earth.

Variation of solar activity has been suggested as one cause of the secular change of the earth's magnetism. The periodic change in

the number of sun spots, which is undoubtedly a symptom of varying solar activity, is paralleled by an 11-year period in the secular change, and Bauer has attempted to trace a relationship between changes in the earth's magnetism and the changes of solar activity indicated by Abbot's observations of the amount of heat given off by the sun. Abbot's observations have not yet been going on long enough, however, to draw any definite conclusions.

Any theory of the earth's magnetism based on electric currents either within or outside the earth must take account of the currents actually observed, and one of the features of the progress of the past twenty-five years has been the awakening of interest in the study of atmospheric electricity and earth currents and the development of instruments for measuring them which can be relied upon to give results of the required accuracy.

Before long we may also expect the increase in our knowledge of radio transmission to throw light on electrical conditions of the atmosphere at higher levels.

From this summary of the accomplishments in the field of terrestrial magnetism during the first quarter of the twentieth century, it will be seen that there has been no sudden increase in knowledge, no epoch-making discovery, but just a steady advance. The old problems still confront us, but in a modified form. Their scope has broadened tremendously and any theory to explain the earth's magnetism must take into account the structure of the atom as well as the structure of the universe. At the same time new weapons and new methods of attack have become available and the workers in other fields of science—astronomers, physicists, geologists, chemists—are now the allies of the magneticians. Moreover, an accurate magnetic survey of practically all of the accessible land and water areas and the operation of additional magnetic observatories, better distributed, have provided us with reliable knowledge of the distribution of the earth's magnetism—the facts which must form the ultimate test of any theory.

Finally there has been an increasing recognition of the importance of international cooperation, so well expressed by Rücker in 1898, when he said: " For those who would unravel the causes of the mysterious movements of the compass needle, concerted action is essential. They can not indeed dispense with individual initiative or with the leadership of genius, but I think all would agree that there is urgent need for more perfect organization, for an authority which can decide not only what to do, but what to leave undone." We may confidently expect that the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union will eventually develop into an organization of the character suggested by Rücker.

SOME CAUSES OF VOLCANIC ACTIVITY[1]

By Arthur L. Day

[With 3 plates]

Several years ago I had the privilege of presenting to the Institute some conclusions respecting the sources of the energy through which the lava lake in the crater of the Volcano Kilauea (Hawaii) was maintained in a fluid condition. The evidence then offered was obtained in association with E. S. Shepherd,[2] from observations on the ground and in the laboratory, and may be reviewed somewhat briefly as follows:

Observations of the temperature of the lava lake, taken morning and evening and often at intervening hours of the day and night through a period of two months, revealed very considerable changes of temperature for so large a body of liquid magma. On June 13, 1912, for example, the surface temperature was 1,070°. On July 6, 1912, it was 1.185°. Temperatures as low as 950° have since been measured in the lava lake, and in its less active pools any temperature down to the point of actual solidification may be encountered. The lake in 1912 had the form of a single pool without partitions, differences of level, or islands, and was approximately 800 feet long by 500 feet wide (pl. 1, fig. 1). The depth of course was problematical and not subject to direct observation except that the lava level rose and fell by small amounts daily and observations over a period of years have shown maximum differences of about 700 feet; the containing basin must therefore have had a depth greater than this. In June, 1912, when these temperature observations were made, the lava stood about 200 feet below the rim and therefore some 500 feet above its lowest observed level during those years. The mass of lava contained in the basin was therefore very considerable and a rise in its temperature from 1,070° to 1,185°, 115° within 23 days, must involve a very large and very rapid access of heat from some source below other than new lava, for the quantity of lava contained in the crater during this 23-day interval under observation was substantially constant.

[1] Address delivered on the occasion of the Centenary Celebration of the founding of the Franklin Institute, September 17, 18, and 19, 1924.

[2] Arthur L. Day and E. S. Shepherd, Water and Volcanic Activity. Bull. Geol. Soc. Am. 24, 573–606, 1913. Smithsonian Annual Report 1913, pp. 275–305.

It is important to note further that islands are frequently present in the lake which have an upward and downward movement of different character and period from that of the fluid lava; also that when a fall of the fluid lava occurs it often exposes what appears to be solid material only a few feet below the previous liquid surface, with no relation to the 700-foot level or to any deep-seated point. Such observations compel the admission that the material contained within the lava basin is considerably diversified in its physical state;[3] some is very fluid and some nearly or quite rigid.

This observation led to a rough laboratory test of some significance. On those occasions when the lake overflows its banks, which is a matter of daily occurrence during the rise of the lava column, there is visible movement of the fans and rivulets of new lava over the crater floor until they are so far cooled down that hardly a trace of red glow from them can be seen. The lowest temperature at which movement can be detected is therefore of the order of 600°. A fragment of this same lava brought to the laboratory and reheated will not flow under its own weight until a temperature in the neighborhood of 1,300° has been reached. Such an observation is significant of a change of composition and yet the only change of composition possible must be in the amount of volatile matter (gas) in solution in it. Gases are given off in abundance during cooling and their loss takes away from the lava its fluidity over a considerable range of temperature.

This observation taken with the other perhaps explains why the physical state of the lava in the basin is thus discovered to be partly rigid and partly fluid, partly porous and partly dense—its gas content is variable; and a further consequence is altogether probable, namely, that there are differences of temperature throughout the mass of material filling the crater greater even than the observed differences at the surface.

Moreover, during this period of continuous observation in 1912 it was uniformly noticed that an increase in the amount of gas discharged at the surface of the lake was always accompanied by a rise in surface temperature, and conversely during falling temperature the gas fountains diminished in number. A photograph taken at a time when the temperature was highest (July 3, 1912) offers a distinct record of more than 1,100 fountains distributed almost uniformly over the surface of the lake (pl. 1, fig. 2) while at other times no fountains at all are to be seen for intervals of a minute or more, and then only an occasional one appears. This observation immediately led us to the conclusion that there is a causal relation be-

[3] T. A. Jaggar. Seismometric Investigation of Hawaiian Lava Column. Bull. Seism. Soc. Am. 10, 160, 1920.

1. THE LAVA LAKE OF HALEMAUMAU IN JUNE, 1912, SHOWING LOW GAS CONTENT

2. THE LAVA LAKE AT ITS PERIOD OF MAXIMUM ACTIVITY, JULY, 1912

tween the amount of gas discharged through the lava and the temperature of the fluid lava itself. The gases somehow contribute to the heat of the lava body.

One of the purposes of this expedition of 1912 was to collect gas from the lava basin at Kilauea if it should prove in any way practicable to do so. We were accordingly equipped with collecting tubes, pumps, and pipe lines, but it was some days before a favorable opportunity offered. Just how fortunate we were in this collection we did not then appreciate, nor indeed for some years afterward, but it is probable that the gases then collected from a lava fountain on the crater floor, immediately adjacent to the lake itself, contained less evidence of contamination by atmospheric air than any volcano gases collected before or since. The conditions under which these gases were collected have been described before[4] and need receive no detailed attention at this time. They were studied in part by extemporized tests on the ground and in part through careful analysis in the laboratory some time later.

Two conspicuous features were revealed by these studies which bear intimately upon the subject of this paper and upon the study of volcanism in general, namely, (1) that the gas content of the different tubes filled at that time was widely different; (2) that the gases, whose composition we determined, could not be in equilibrium at the time and at the temperature of their escape from the lava. The first observation leads directly to the conclusion that the composition of each bubble which breaks through the surface, even from the same opening, is different; the second to the conclusion that the gases are necessarily in process of reaction at the time of their release. From our knowledge of gas reactions it follows, further, that gases still in process of reaction at the time of release after passage up through the basin of liquid lava, must have been in process of reaction throughout their upward progress, that is to say, there must have been bubbles of gas of different composition uniting beneath the surface at frequent intervals during this excursion.

The analyses of the gases collected at that time revealed the presence of the following gases in different proportions in the collections: N_2, H_2O, CO_2, CO, SO_2, free H, free S, Cl, F, and NH_3. Argon was also found after the first announcement was made. It is of course plain that free hydrogen can not exist side by side with SO_2 or CO_2 at a temperature in the vicinity of 1,000°. Nor is free sulphur appropriately found in this group at 1,100° C. Indeed the fact that the proportions of these gases vary from tube to tube when collected by continuous pumping from the same opening

[4] Arthur L. Day and E. S. Shepherd, op. cit.

plainly indicates that their relation can not be a constant or a stable one.

Our knowledge of the reactions which must be taking place between these gases is adequate to establish the fact that heat is being contributed to the lava mass in consequence of these reactions going on within it. We have, therefore, certainly hit upon one of the sources of energy which serves to maintain the particular type of volcanism which is familiar to all at Kilauea. Very probably we have done somewhat more than this. If we have established the fact that continual reaction is going on during the passage of the gases through the liquid lava, whereby heat is contributed to the lava, it is a probable consequence that the temperature reaches its maximum at or near the surface. The consequences of this decision are somewhat far-reaching if one is minded to pursue them to their logical conclusion. For example, it appears to follow that the temperature in the basin will be lower as we go down into the lava, rather than higher, whence it is reasonable to suppose that the entire phenomenon is local and superficial rather than deep-seated.

Dr. T. A. Jaggar, director of the Hawaiian Research Laboratory, has already confirmed this deduction regarding the temperature gradient by actual measurements of the lava temperature.[5] He used for this purpose a stout iron pipe within which groups of Seger cones were fastened at regular intervals and thrust it into the lava as far as he could (20 feet). Temperatures were found to be somewhat variable but lower by 100° or more than at the surface. The existence and behavior of the islands and the heavy semirigid masses below the surface upon which they rest, also indicate a lower temperature below, for the circulation of gases in these masses will be considerably hampered. Very likely they are themselves losing gas more or less continually and thereby losing their fluidity. In any event such a temperature distribution does not afford support for the old hypothesis that volcanoes are "safety valves" to insure the stability of a molten interior, indeed they afford not the slightest indication of the existence of a generally molten interior.

In a book which appeared quite recently Mr. Harold Jeffreys, of Cambridge University, offered a careful analysis of existing evidence of the manner of formation of the earth[6] and the probable state of its interior. His reasoning has seemed to me to include more of modern physics and chemistry than the reasoning hitherto applied to the constitution of the earth. He figures that the gaseous mass, presumably split off from the sun by tidal rupture due to another

[5] T. A. Jagger, Volcanologic Investigations at Kilauea, Am. J. Sci. (4), 44, p. 208 et seq., 1917.

[6] Harold Jeffreys, The Earth; its Origin, History and Physical Constitution. Cambridge, 1924.

heavenly body passing too near, condensed within a comparatively short time to a liquid nucleus. This nucleus in its normal convection cooling then acquired a crust which broke up and sank as soon as formed, its specific gravity being measurably greater in the solid than in the liquid state. It is no more than a generation since distinguished physicists were still in doubt about the relative density of solid and liquid lava, and some then believed that the crust ought to float as readily upon the molten interior of the earth as patches of crust float upon a liquid lava basin, like that at Kilauea (pl. 2, fig. 1). Closer observation, however, has since established the fact that the floating is but temporary and is due to nothing more than the accident of gas accumulations beneath these patches of crust, which give sufficient buoyancy to support them on the surface for a long time, but only for so long as they remain perfectly poised. The rise of a bubble more violent than the rest, which is sufficient to tilt one of these blocks but a very little, or an overlapping wave in the lava surface, will quickly cause them to lose the supporting gases and to glide out of sight beneath the surface much as a piece of sheet iron sinks in water.

The normal behavior of a crust forming upon a fluid mass highly charged with gas, such as we must believe the nucleus of the earth to have been, is to sink, and so Jeffreys concludes that though the first blocks to sink were undoubtedly remelted presently in the course of their downward movement and so merely helped to cool the magma, eventually the sinking crust accumulated at the center and the resulting earth became in consequence something of a honeycomb structure, the rigidity of which may quite properly be equal to that of steel, as has been so completely shown by the tidal studies of Michelson and Sir George Darwin, and that any portions remaining liquid can be nothing more than the product of local conditions which presumably are slowly passing away.

This concept of the formation of the earth as a whole readily lends itself to the interpretation of volcanoes as we find them. It is extremely difficult to conceive of a volcano as the safety valve of a molten interior, as the older geologists were accustomed to think of it, or of a molten layer concentric with the crust as it was later conceived to be, so long as two such openings continue to exist side by side in the Island of Hawaii, one of which (Mauna Loa) is 10,000 feet higher than the other (Kilauea) and yet liquid lava emerges more frequently and in greater quantity from the higher opening, or its subsidiaries, than from the lower. It is also a matter of record that greatly increased activity in the one basin rarely finds an echo in the other. The liquid lava of Hawaii is at least two and one-half

times heavier than water. If these two outlets were connected with a common liquid interior the lava column in the higher conduit would be pressing for discharge at the lower opening, not at the higher, and with a pressure of the order of magnitude of a thousand atmospheres upon every square inch of its area. Similarly the volcanoes of Central America and of the Alaskan peninsula maintain each its independent behavior apparently regardless of what is happening to its neighbors. So far as the record of field observations goes therefore the number of simultaneous eruptions which have occurred in neighboring volcanoes in recent time is so small as to leave little room for any other explanation than coincidence.

If for these several reasons we limit our conception of a volcano to a purely local phenomenon arising from unusual local conditions, and if we may assume that other observations above outlined offer reasonable ground for the supposition that gases, reacting among themselves, contribute materially to the heat necessary to maintain a small lava basin like that at Kilauea in a liquid state, then we have two further steps to take in order to give to this concept a tangible and reasonably independent existence. First where may such an extraordinary phenomenon as a volcano be supposed to take its origin, and second by what means is the indispensable heterogeneity among the gases maintained in consequence of which the reactions occur? Obviously this is reasoning somewhat beyond any phenomena actually observed, but the underlying region beneath a volcano will perhaps never be accessible to direct observation, so that inference from the best experience we have must be drawn upon to complete the picture.

Before attempting to indicate the direction in which this search leads it will be helpful to consider the phenomena at another volcanic center which was active between 1914 and 1917. I refer to Lassen Peak in California. This volcano is entirely different in its behavior from Kilauea. Instead of an open basin of liquid lava, more or less continuously active but rarely overflowing, here is an explosive volcano which emitted no liquid lava and only once during its four years of activity reached the temperature indicated by red heat.

The outbreak at Lassen Peak began with an explosion in the summit crater in the early spring (May 30, 1914), the first outburst breaking through snow of considerable depth. These explosions continued at intervals of four or five days throughout the summer and autumn, possibly to some extent in the winter season also, but Lassen Peak is over 10,000 feet high and the summit during the winter season is shrouded in cloud. In May of 1915, almost exactly one year after the initial explosion, came three days of terrific activity, during which the dust cloud reached a height of 25,000

1. THE LAVA LAKE, SHOWING GREAT PATCHES OF CRUST FLOATING UNDER THE BUOYANT ACTION OF GASES RELEASED BENEATH. JULY, 1912

2. LASSEN PEAK AFTER THE ERUPTION OF MAY 22, 1915, SHOWING THE DEVASTATED AREA EXTENDING FOR 5 MILES TO THE NORTHEAST OF THE MOUNTAIN

feet above the summit of the mountain and blocks the size of a man's hand were thrown for 10 miles. During this culminating outbreak, or just before it, the old volcano plug forming the floor of the crater was raised 300 feet or more to a position level with the crater rim, the force behind it apparently being just insufficient to blow it completely off the mountain and so to expose the volcano hearth. The point of greatest weakness then proved to be at the northeast side of the inclosing cone, somewhat below the summit, and two devastating, horizontal explosions, the latter concluding the period of most violent activity, found vent through this opening. Although the adjacent valleys of Hat Creek and Lost Creek were stripped of all vegetation for a distance of more than four miles by these horizontal blasts (pl. 2, fig. 2), no fire appears to have been set by the explosions, save momentarily on the face of a steep cliff directly exposed to the second blast, and even this was confined to a small area of dead leaves and twigs which supported combustion for no more than a few moments. Red-hot ejecta at the summit or illuminated smoke clouds at night were seen only once (May 19, 1915) and then the color was described as "deep red," indicating a temperature not higher than 750°. Generally the ejecta which were thickly strewn about the country adjacent to the crater were not warm enough to melt the snow on which they fell and even when of great size they broke through the snow without melting it away. In midsummer likewise no case is known where the ejecta were hot enough to kindle a forest fire, although a careful watch was kept by the Forest Ranger Service through four summers for just such a contingency.

Following this outburst the eruptive activity gradually subsided, the year 1916 offering but a few mild explosions and 1917 only a short concluding outbreak (also in May), of considerable violence while it lasted, but not comparable either in volume or intensity with the great outbreak of May, 1915.[7]

This brief outline of the character of the eruption of Lassen Peak is sufficient to show that in spite of the violence of the explosions no evidence of the high temperatures of Kilauea or Vesuvius[8] appeared at the surface during the entire period of activity. There were steam explosions of tremendous volume and power, but no local development of heat by chemical activity, such as has been described in the case of Kilauea, was detected at any time.

In considering this case it is appropriate to emphasize the fact that there has been no other eruption of this volcano since the region

[7] For further details and laboratory studies see Arthur L. Day and E. T. Allen, "The Volcanic Activity and Hot Springs of Lassen Peak," Carnegie Inst. of Washington, Publication No. 360, 1925.

[8] For an account of activity of Vesuvius in recent years see F. A. Perret, "The Vesuvius Eruption of 1906, Study of a Volcanic Cycle." Carnegie Inst. of Washington, Publication No. 339, 1924.

was inhabited by white men, and geological conditions indicate that at least 200 years have elapsed since the last show of activity.

If a volcano is assumed to be a slowly cooling system maintained by residual heat from a local hot zone below the surface, then what manner of mechanism is it which can account for the sudden development in such a cooling system, of violent explosive activity sufficient in volume to extend over several years, and of such intensity as to cover the surrounding country with boulders of considerable size, without displaying evidence of high initial temperature or contributory chemical reactions?

It has been a long search to find an explanation which appeared properly to account for an outbreak of this kind, but a suggestion has at last been found, partly as a result of theoretical reasoning and partly from experience in the laboratory, which appears to account for it completely and at the same time to go far toward elucidating the entire problem of volcanism.[9] Freed from chemical terminology the mechanism is simply this: A silicate solution in its liquid state can take up water in solution in considerable quantity. A simple solution of silica and potash when heated under pressure in the laboratory is capable of taking up as much as 12.5 per cent of water in solution. A rock magma in the earth is just such a silicate solution, although more complicated in character, and is entirely competent to carry 5 or 6 per cent of water in solution under appropriate conditions.[10] If it should happen that the lava beneath a volcano carries such quantities of water in solution, then all the phenomena of volcanism become appreciably clearer, for in the 8,000 or more analyses of crystalline rocks of igneous origin which have been gathered together by Washington and published by the United States Geological Survey[11] there is none containing more than 1½ per cent of water and less than 1 per cent is usual. This must mean that in the process of crystallization of the rock from the magma the water content is for the most part discharged. Should it happen that this discharge of water takes place in a closed space then immense pressures might develop and explosive activity of tremendous intensity might result. Furthermore if the amount of participating magma were large and the rate of crystallization considerable, such activity might continue for long periods of time.

Beneath the surface, magma basins are of course inaccessible to direct observation, but two facts have been noted in the study of

[9] G. W. Morey. "The Development of Pressure in Magmas as a Result of Crystallization." Journ. Wash. Acad. 12, 219, 1922. Arthur L. Day and E. T. Allen, *op. cit.*

[10] Cf. J. W. Judd *et al.* "The eruption of Krakatoa and subsequent phenomena," p. 36 (Rept. of Krakatoa Com., Roy. Soc. London, 1888).

[11] H. S. Washington, "Chemical Analyses of Igneous Rocks, etc." U. S. Geol. Surv. Prof. Paper 99, 1917.

volcanoes which tend to confirm this reasoning. It has already been stated that the lava lake at Kilauea has a temperature, usually, between 1,000° and 1,200°, and fluid lava overflowing the rim of the basin at that temperature, still remains fluid at 700° or 800° (red heat.) This is of course representative magma or lava which is in process of crystallization. If samples of this lava be collected after solidification and reheated in the laboratory, they can not be brought again to molten condition below 1,300 degrees. It is, therefore, clear that the fluidity of the lava in the basin is due primarily to the volatile ingredients which it contained and has discharged during crystallization, of which water is the chief. In complete accord with this the great outbursts of gas and dust-laden steam from the more violent volcanoes, like Vesuvius or Lassen Peak, are nothing other than this volatile content of the magma below, discharged explosively.

It sometimes happens that volcanic magma either through peculiarities of chemical composition or through sudden exposure, whereby it is quickly chilled, solidifies without crystallization. Such volcanic glasses are commonly called pitchstones or obsidians. A very considerable mass of such obsidian is familiar to all tourists in the Obsidian Cliff at Yellowstone Park. In smaller quantities obsidian is frequently found in nearly all volcanic regions. Such uncrystallized volcanic magma when analyzed is often found to have retained much more of its water content than the 1½ per cent maximum which has just been cited for crystalline rocks.[12] Here, therefore, is direct confirmation—i. e., as direct as the inaccessible character of the subject is ever likely to permit—of the conclusion that the water content of magma before crystallization is greater than the water content of the rock which forms from it. During the process of crystallization, therefore, this water must in some manner be discharged.

If we apply these observations to Lassen Peak and suppose a body of magma in process of slow crystallization at relatively low temperature to exist beneath the mountain, and suppose further that the water set free during the crystallization process is maintained under pressure in a closed chamber, there is danger of a violent outbreak whenever a structural weakness develops in the containing vessel. Lassen Peak is situated in a region often visited by earthquakes. It, therefore, requires no violent stretch of the imagination to believe that one of these earthquakes did in fact weaken the structure early in 1914 and that in consequence of this a small explosion through the floor of the summit crater occurred. More or less in confirmation of this supposition the forest rangers who first visited the mountain

[12] Cf. J. W. Judd, *op. cit.*

on the day following the explosion noted two cracks extending east and west from the explosion opening for a hundred feet or more. The explosion itself, so far as may be gathered from witnesses, was wholly inadequate in volume to split open the mountain, and indeed the small crater formed by the explosion is reported to have been no more than 20 by 40 feet and extended only a few feet into the loose scoriaceous material covering the crater floor.

This discharge of steam in violent explosion was followed by similar outbreaks at intervals of three or four days during the next seven or eight months, the periodicity being determined no doubt by the rate of crystallization and the amount of the overlying load. In general the volume and intensity of the successive explosions increased as they proceeded, which might reasonably be expected, as more and more of the crystallizing mass came to feel the release of pressure after the opening had been made.

The laboratory study of such solutions indicates a further possibility through which the early stages of such an outbreak might be expedited. The fact that even when the explosions had reached their maximum intensity there was no development of high temperature, suggests that the magma below may itself have been at a relatively low temperature, ultraviscous and inert through undercooling, that is to say, being inclosed within an impervious containing vessel at comparatively low temperature, crystallization had slowed down until considerable portions were cooled below the temperature of normal crystallization while still in the vitreous state. It is of course well known that silicate solutions (cf. window glass) are prone to crystallize with extreme slowness, otherwise probably we should have no glass industry. In such an inert mass therefore in which crystallization was proceeding thus slowly, the advent of water vapor from without would have the effect of diminishing the viscosity and increasing the rate of crystallization.

Following the first explosion at the summit of Lassen Peak it was noted that the great body of accumulated snow within the summit crater was rapidly melting and flowing into the explosion cracks. This water must have found its way to the volcano hearth at first by percolation and later, within the hot zone, as steam. We know from laboratory experiment that steam is readily soluble in such an undercooled silicate magma with the effect of increasing its fluidity and thereby precipitating crystallization or increasing the rate of crystallization already going on. The operation of crystallization itself, as has been shown above, sets free more water so that the operation becomes more or less self-perpetuating so long as any considerable amount of magma remains uncrystallized within reach of the outlet channels (reduced pressure). This explanation

appears adequate to account both for the initiation and the progress of explosive volcanic activity at Lassen Peak during the period of 1914 to 1917. It also indicates the source of the vast amount of water vapor which is given off in the course of a long series of explosive eruptions.

In this discussion of the phenomena at Lassen Peak we appear to have reached an answer to one of the two questions posed earlier in this address, namely, the point of probable origin of the gases which participate in volcanic activity. They are in solution in the crystallizing magma and their release takes place under appropriate conditions of temperature and pressure when this magma crystallizes to rock. Chief among these volatile ingredients is undoubtedly water in most if not in all cases. If water be substantially the only ingredient, as at Lassen Peak, then the volcanic outbreak will consist in discharges of dust-laden steam, and such solid material as may be carried out by attrition. If temperatures are higher and the volatile ingredients include chemically active gases such as chlorine, fluorine, sulphur, hydrogen, and the like, then an accelerated type of development may be expected, due to the higher temperatures resulting from the combination of these gases when oxidized either through reactions within the magna or with oxygen from the air. Under such conditions the magma may be forced out in liquid condition (lava flow) and may crystallize in the open air. After observing the persistance of the open lava lake and noting, as Professor Jaggar has been able to do by measurement, that the temperature at the surface is higher than it is immediately beneath the surface, it again requires but little of the imagination to enable one to understand how such gas reactions may provide the necessary energy to maintain the lake in fluid condition. The origin of the gases here, as in the case of Lassen Peak, must be sought in crystallizing magma at different depths where differences of temperature and pressure must be responsible for very considerable inhomogeneities (differences of concentration) in the gases from different local sources.

The Kilauea crater is not appropriately pictured as an ordinary boiling flask with a long narrow neck. It is very doubtful if we have any ground for such a picture. At any rate during the past summer (1924) when the lava lake had been drained away through subterranean channels and the gases were escaping explosively from the empty basin, the crater was enlarged by the explosions to about 3,500 feet in diameter and 1,500 feet in depth. The volcanic throat was thus laid open to a depth more than twice as great as on any previous occasion since it came under the observation of white men, and a rare and precious opportunity was offered to see what manner of material occupied the next 800 feet immediately under the lava lake,

which has so long filled this throat to varying depths from a few feet to as much as 700 feet or more.

To those who have thought of the volcano crater as a downward extending pipe or conduit through which the lavas for centuries have been quietly poured out upon the surrounding terrane the appearance of the enlarged and deepened opening must have been an unexpected revelation. It appeared quite dry—no freshly cooled volcanic glass (obsidian) or partially crystallized lava was visible below, nor was any found among the fragments thrown out (pl. 3, fig. 1) by the explosions. The lava fragments were from older layers than any before exposed at Kilauea, completely crystallized, nearly free from bubbles, rather fine grained though rich in olivine and feldspar phenocrysts like the lavas from its great neighbor, Mauna Loa, but in physical appearance totally unlike the Kilauea flows which have almost come to be regarded among geologists as a fixed type.

At one side of the great bowl, about 600 feet above the bottom, was an area some 500 feet in its transverse dimension and more than 100 feet thick, which showed here and there a trace of red at night. The surface also had the appearance of fresh Aa lava, which occasionally flaked off in considerable areas, revealing a bright red patch beneath. Above it on the rim a hot air-current was continually depositing fine flakes of freshly-oxidized iron-bearing scale. This may have been one of the feeders of the lava lake. It was certainly the hottest spot left exposed in the empty basin. Another smaller area in one corner of the bottom was distinguished by a half dozen roaring gas outlets whose throats glowed red at night. This may have been a smaller feeder. When the lava began to return to the pit in July it spouted out from a point high up on the talus pile on the opposite side of the basin in a fountain 175 feet high. This must have been from a third feeder. No others have so far been discovered.

Instead of the boiling-flask picture, therefore, we should think rather of a central collecting tube, with many more or less widespreading branches below, leading to local chambers in which crystallization is proceeding under different conditions of temperature and pressure. That a number of such branches exist is only discovered on a rare occasion like the present summer when violent explosions have cleaned out the lava basin and enlarged it to many times its former volume. Then it is seen that the openings leading into and out from it are on the side walls, while the bottom is to all appearance solid, old, and (relatively) cold. Even the solid ejecta which were thrown out during this period of violent activity include no obsidian masses and no lava as recent as that represented in the lava lake and in the flows of recent years.

1. THE EJECTA THROWN OUT IN THE MAY (1924) ERUPTION OF KILAUEA

2. SHOWING AN OUTFLOW OF LAVA FROM THE TALUS, ABOUT 80 FEET ABOVE THE LAVA LAKE, JULY, 1912

That the gases from these different sources differ in composition is abundantly shown by their continual reaction when they meet in the lava lake, as has been explained in the earlier part of this paper.

That the fluid material in these individual pockets is under different pressures as well as different temperatures is also shown by many observations of small streams of lava which emerge from the talus pile, often 100 feet or more above the level of the lava lake, and flow down into it (pl. 3, fig. 2). Such a flow, observed in June, 1912, lasted for several days and released a very considerable body of lava.

If the lava lake represented the outlet of a single subterranean magma chamber with which it is supposed to be connected through a single neck or funnel, then the establishment of a second conduit from one to the other will not be competent to deliver lava at a higher level than the first, or gases of different composition. A separate chamber and an additional source of energy are necessary for that. Thus it has happened that the heterogeneous character of the gases collected, the temperature conditions within the lava basin, the appearance of the crater when free of all its liquid lava and the dynamic relations within the lava body when present in the crater, all point to many sources rather than to a single source both of gases and of magma.

An interesting sidelight of quite another kind has lately been thrown on this problem from an entirely unexpected source. In the month of July, 1919, Professor Jaggar took advantage of a favorable opportunity to make a continuous series of observations, extending through the entire month, of the level of lava in the basin of Kilauea. The observations were made by vertical triangulation from datum points on the rim of the pit at intervals of 20 minutes day and night with the purpose of ascertaining whether or not a lunar or solar influence upon the lava mass could be established. The examination of the data was made by E. W. Brown,[13] than whom there is no one with wider experience in the discussion of tidal phenomena, and although the curves at first sight appeared to be of periodic character and were so regarded by Jaggar, no more than an inch or two in apparent changes of several feet could be attributed by Brown to luni-solar influence. Had the magma chamber been very large, an unmistakable tidal effect would certainly have been found.

And so we return from this investigation also to the conclusion that volcanoes are local and superficial developments representing (geologically) the last stages of crystallization in a mass of magma below, of which little remains fluid and this in small (as geologic

[13] Ernest W. Brown, "Tidal Oscillations in Halemaumau, the Lava Pit of Kilauea," Am. Journ. Sci. (5), 9, 95, 1925.

dimensions go) pockets which are quite variable in gas content, pressure, and conditions of chemical equilibrium.

There were times even in late geologic history when quite different conditions prevailed, when masses of fluid magma were larger and poured out through crustal rifts several miles in length without signs of explosive activity or any restraint upon complete freedom of crystallization and release of their volatile content. Such conditions gave us the successive flows known as the Deccan traps, the Stormberg lavas of South Africa, and the great basaltic outflows of the Snake River Basin and adjacent territory in this country, which covered nearly 250,000 square miles. Latest of these and appropriately smallest in extent is the flow from the Laki rift in Iceland in 1783. It may well be that such outpourings are past. It is a rare volcanic outburst in modern times which yields as much as a cubic mile of lava. Matavanu, in Samoa, is reported to have released this quantity in a continuous flow through the six years ending in 1912.

Through all of these studies our conclusion seems to stand fast wherever it is applied, namely, that the outstanding factor in determining the character of modern volcanism is the gas content of the crystallizing magma. If this be mainly of steam released in a closed chamber, as a Lassen Peak, then only steam explosions are to be expected as the surface manifestation of the crystallization of the magma below; if to the steam are added such chemically active gases as chlorine, sulphur, hydrogen and the hydrocarbons, then chemical reaction between these will be a sufficient cause of higher temperatures and lava flows of the character well known at Vesuvius, Stromboli, or Kilauea.

GEOLOGY IN THE SERVICE OF MAN[1]

By Prof. W. W. Watts, Sc. D., LL. D., F. G. S., F. R. S.,
President of Section C (Geology) of the British Association

INTRODUCTION

Although geology in the modern restricted sense of the word is over a century old and possesses a flourishing family of descendant sciences, it is still possible to trace its immediate parentage and ancestry. The only begetter is unquestionably the mining industry, and it is to the ample exposure of rocks in mines, their condition and arrangement in the simpler mining districts, and the necessity for accurate knowledge of these districts with regard to composition, succession, and arrangement, that we owe the earliest detailed knowledge of the earth-crust in certain restricted localities.

The other parent was of more advanced years, and may be described as "insatiate curiosity"; the natural instinct for observing and collecting odd and bizarre "rarities" found in excavations or seen in natural rock exposures. These fossils, using the word as then employed and not in the restricted sense now usual, naturally kindled interest by reason of their natural beauty, their regularity in shape, their properties, their likeness to, and yet their tantalizing difference from, the appearance of living animals and plants. It was tempting to draw inferences from their occurrence and to explain them either by marvellous operations which fuller understanding of nature had not then inhibited, or by means of catastrophic events like those familiar in the Mosaic cosmogony.

Although much had been observed and thought out by his predecessors, it is to Werner that we owe the most successful generalizations in a mineral-bearing district; generalizations which gained a wide influence owing to the enthusiasm and eloquence that attracted students from all over the world and imbued them with the desire to confirm and spread the master's ideas. To Werner also is due a reaction from the fanciful speculations of preceding periods with which he was so impatient that he proposed to drop the very term

[1] An address delivered before Section C (Geology) of the British Association at Toronto, 1924. Reprinted by permission from the Geological Magazine, Vol. LXI, Nov., 1924.

geology and to substitute his own word "geognosy" for it, a word intended by him to separate the knowable from the unknown.

Probably there would have been less controversy between Neptunists and Plutonists had Werner committed more of his work to writing, and not left us dependent on his pupils for their versions of his views. But it is a curious fact, and one probably not dissociated from a geologist's devotion to field study, that many of those who have made great advances have either disliked the act of writing or have been unfortunate in the style of their written work. It will be sufficient to couple with Werner in this respect such names as William Smith, Sedgwick, and even Hutton, not to mention those of more recent geologists. It has not been from Smith alone that views and conclusions have had to be extracted almost by force and committed to writing by faithful devotees.

Yet, after all, this failing has not been without its advantages. The joy of such men is in discovery, and they are happy and contented when, but only when, they feel perfect confidence in their conclusions. If their results then get published it is with an authority and finality denied to lesser men. In the progress of their work they are apt, as in fact all of them did, to infect their friends and students with the enthusiasm that only the spoken word can arouse. And to others they have always been most generous, even lavish, in giving ideas and momentum, partly out of sheer good nature, but much more through the desire to watch the germination of the good seed that they sow broadcast and to see the harvest reaped, not by or for themselves but for the advantage of the science whose welfare is their chief care.

During the early growth of the science, as in human families, it was the influence of the other parent that was most felt. From the earliest thinkers of Greece and Rome we have record of numberless observations and discoveries, sometimes in respect of minerals or organic fossils, sometimes of unusual phenomena in mountains or volcanoes or in the relations of sea and land, generally leading to reasoned conclusions, many of them perhaps fanciful, some even absurd, but others so sound and far-seeing that they have not been upset at the present day. Many other countries, joining the favored ones along the Mediterranean, carried the torch forward, and in spite of the clogging influence of the vested intellectual interests of the day, the stock of knowledge gradually grew, until we find that Leonardo da Vinci was able to make as great an advance in the knowledge of the earth as he did in his own arts of painting, sculpture, and architecture.

It is true that during this period observers had a tendency to confine themselves too exclusively to one or other side of their sub-

ject and were in the habit of reproaching one another with neglect of neighboring branches, but even this made for progress by stimulating competition and discussion.

In spite, however, of all that had gone before in the fields both of fact-collecting and of speculation, it will be admitted that no single man made so great an individual advance, or placed it upon such an enduring foundation, or did so much on which the future of his science was to depend, as William Smith. And it is noteworthy that the spur to his discoveries was not so much his theoretical views or even his scientific zeal, as a plain and practical issue—the finding of a short cut to speedy and accurate land valuation.

The discovery by the "father of English geology" that fossils are the "medals of creation" and that strata are each characterized by special suites of organisms was certainly one of the greatest ever made in the history of geology, and upon it have been founded, directly or indirectly, almost all the latter advances in the science. But for the fuller utilization of his discoveries there were needed the artistic faculty and a wide knowledge of places and people, both of which he fortunately possessed. Thus he was able to introduce handy, crisp, easily remembered and pleasantly sounding local terms to characterize his "formations," and to represent the outcrop of strata on maps which were not merely topographical but, for the first time, were tectonic also. So well did he discharge this latter function that a comparison of his general map of England with the latest production of the Geological Survey on a scale at all comparable with it fills one with astonishment at the amount of work accomplished by him single handed, and with admiration for his accuracy.

It is strange that, in the amateur and official work which followed during much of the nineteenth century, so little interest was taken in the industrial application of geological knowledge which, in Smith's hands, had been so productive. The science had, as has been said, the "landed manner," and the dignity of its application to arts and industries was little appreciated. A former director of the Geological Survey of Great Britain, Sir Andrew Ramsay, quoted with approval the saying of one of his colleagues, "it is but the overflowings of science that enter into and animate industry." And thus, though the scientific side of geology stood to gain much otherwise unattainable information from contact with its economic application, this source of knowledge was not fully utilized, and an air of mutual suspicion—not wholly unjustified—grew up between "theoretical" geologists and those who applied geology to mining and other economic problems. Fortunately this feeling is passing away; the two sides have found that each is indispensable to the

other, and geologists are everywhere cooperating with those whose work is connected with the discovery or exploitation of the mineral wealth of the earth-crust.

MATERIAL SERVICE

Coal.—The first branch of industry to which geology made itself indispensable was coal mining. Geology has long been in close contact with its problems, in mapping the extent of coal fields, collecting information as to the succession of measures and the existence and lie among them of wants, faults, and igneous rocks, tracing the extension and variation of coal seams, and estimating the resources available; and, as seams are worked at increasing depths, and in those parts of fields concealed under thick unconformable cover of more recent formations, the work of the geologist has become more essential and increasingly productive.

It is interesting to observe the application of the "academic" sides of geology to these more recondite problems, in unravelling tectonic complexes, in the collection of facts which may eventually elucidate the precise conditions under which different varieties of coal have originated, in applying knowledge as to the limits of the original areas of coal deposit, in the interpretation of stratification in the light of progressive travel of coal-forming conditions geographically across the coal-producing areas, and in the stratigraphical relationship and exact mode of formation of the covering rock systems.

It is true that the accessibility of coals when first exploited, and their distribution in seams of varying quality, led, and in the newer areas are still leading to much waste; waste on fruitless search in the light of obtainable knowledge, in exploitation of good, thick, and easily worked seams to the neglect of poorer ones, in the non-preservation of satisfactory plans and the consequent leaving of derelict areas, in unsatisfactory drainage, and in the loss of valuable by-products. But there is a corresponding advantage to those of our generation that some exposed areas of complicated structure, and many of the concealed coal fields were left for ourselves and future generations by reason of working difficulties which it would have been premature to face in the time of easily obtained abundance.

Even to-day, in spite of improved technical knowledge, there remain many areas in which information and inference are both scanty, and where difficulties met in working have not yet been surmounted, while there will be in the future ample scope for improved methods and inventions to deal with coal at greater depths than those at which it can at present be economically worked. There is room for much new and more precise study than has yet been devoted to the

variation of coal seams, both in the vertical direction and when traced over the wide areas of their extent. Elaborate and knowledgeable sampling, followed by new means of testing, and these again by new methods for recognition of varieties, have still to be put into practice before it can be said that we are making a justifiable and economic use of the capital reserves stored up in the rocks.

Oil.—While we blame our forefathers for their destructive and wasteful handling of the coal fields, it is ourselves and our own generation that we must blame for serious waste of oil and the destructive exploitation of oil fields that have been permitted. There is no economic subject to which geology has so direct a relation as the occurrence and exploration of oil fields, and nothing in recent times has given so much employment and such valuable experience to geologists all over the world. It is the only example we have of the sudden introduction of a new source of fuel on a large scale in a late stage of industrial development, and it has already revolutionized many branches of engineering practice. The introduction and spread of the internal combustion engine and all that this implies in space economy, cleanliness, labor-saving, and comfort, has been the greatest engineering feature of the late nineteenth and early twentieth centuries, and it has given rise to systems and methods which mankind would be loath to abandon. The whole world is being searched to prolong the good times that we live in; but in spite of the fact that there probably still remains a recoverable percentage in the oil producing areas, and that there must be new fields awaiting discovery, there are already signs that the high oil mark has been reached if not passed. But, again it is no small comfort that although our supply of native oil, easily won and easily refined and applied, cannot last very much longer, there are abundant supplies of oil shale still left, sufficient to take its place for very many decades to come.

Metals, etc.—Although the greater part of to-day's session is to be taken up by papers and discussions on special sides of economic geology by those who are far more competent than I to speak on them, I can not resist the temptation to say a few words on that side of the subject which touches on metal mining. There is probably no subject which has been in the past more dominated by the "practical man," who may be defined as the most theoretical of all men, but whose theories are seldom proved and are often not susceptible of proof. The valuable information that was accessible to him has been wasted because he could not use it to the best advantage, or else it has been lost because he could or would not impart it. On the other hand, the "theorist," as he has been contemptuously named, has been hampered because he

has often only been called in when difficulties were excessive and when the train of facts or reasoning which would have been so valuable to him has been lost.

In Britain the mining industry is so old and the mineral wealth in certain spots was so plenteous and accessible that the metal-mining geologist has had little chance. The eyes have been picked out of the mines long ago, and in certain cases their very bones picked clean, and the country has been left in such a condition that its original state can only be guessed at, and problems of relationship, structure, and origin are past solution. Consequently, it is in the countries which have not been inhabited by successive races of highly civilized peoples, or in relation to substances for which there was in the past little or no demand, that the subject has been susceptible of real advance.

Thus it is that such strides in mining geology have been made in Canada, the United States, India, South Africa, and Australia, where there has been a fair field to work upon, and where preliminary surveys have opened up the country and given an idea of its hidden resources. In no other areas of the world has the work of official surveys been watched more carefully by men of capital and enterprise, and money has rarely been lacking for development where there seem to be prospects of a fair return for it. Fortunately, too, the training of official geological surveyors has provided a type of geologist exceptionally well fitted both to prospect independently and to follow out in minute detail, and from a different viewpoint, the preliminary and less detailed examination which is all that is practicable in an official survey. These men have carried with them not merely competence and enthusiasm, but a thorough belief in scientific principles, an extensive knowledge of borderline sciences, and the ability to apply both principles and methods to the problems involved. In the hands of such men the surest guides are scientific principles, just as in the hands of those with "a little learning" imperfectly understood principles are most dangerous; and as the search for ores becomes keener, and as deposits smaller and more tenuous become worth working, the need for increased knowledge of principle and for minute detail in observation steadily grows.

Fortunately, we have not yet exhausted the existing stores of highly concentrated and singularly pure ores, salines, refractories, etc., and the need is less acute than it will become eventually for much improved methods of concentration and purification. When we feel the pinch it will be necessary to call upon the chemist to endeavor to make available the abundant supplies of less pure and less concentrated materials which will remain over for our

successors when we have picked out the best. This has already been to some extent effected for oil and it is beginning for coal; it must eventually be done for the still less pure sources of these two substances, for less concentrated ores, and the like.

Stone, etc.—The geologist has already done much in the investigation of the qualities of building stones, plastic substances, and the materials for roofing and cement. To a large extent the materials in use are satisfactory in the air and surroundings in which they occur in nature. But the added problems of a town atmosphere, accompanied by increased stresses in large buildings and the modern demands of the architect and sculptor, have still to be met, if our buildings are to be more permanent and our towns to present a less weather-beaten aspect than they now do. New and reliable means of testing are required, and we need a more thorough understanding of the reactions produced by impure atmospheres and the effects of the presence or absence of protective or destructive organisms. Future investigation will react in the production of more satisfactory preservatives, and it may lead to increased production and adoption of artificial stones devoid of the qualities which undermine the power of resistance of natural stones; at the same time more control over color and shaping may be obtained.

Roads.—Closely akin to the subject of building materials comes that of stones used for flagging, paving, and metalling of roads, to the provision and study of which the geologist has already very largely contributed. New problems are daily introduced as road traffic becomes heavier and as roads are required to be freer from dust and vibration. Already many waste products have come into valuable utilization, and a wide range of road metals which can be called upon for these purposes exists in almost every country.

In the siting of roads, railways, and canals, however, geology could render much more useful service than it has yet been called upon to give. The routes that are cheapest to make are by no means the cheapest to maintain, and the geological survey of routes would very often suggest slight deviations which would be more economical in the end than when the shortest route compatible with the gradients is taken.

The princes of road makers in the old world, the Romans, were perhaps too heroic in their dealings with gradients, but they exercised quite remarkable skill in choosing such directions as to secure the least formidable slopes consistent with the general design of their routes. Their roads were, however, constructed primarily for strategic purposes and secondarily for transport, and it was necessary to sacrifice something. On the other hand, the constructors of

the coach roads were, perhaps, too sensitive to the psychology of their horses and the limitations of their vehicles, and their roads are not ideal for present-day traffic. Some compromise seems to be required between the two methods, and not the method of the Romans tempered by the cuttings and tunnels of the railway engineer. Now that we have a vehicle that rejoices in a hill, whether for or against it, and for the first time have a means for hill climbing at speed, it is a pity to flatten down gradients too much; and though it is legitimate and even necessary to remove dangerous crossings and curves, it should be remembered that an everlasting straight vista is as exasperating to a driver as it is heartbreaking to a horse. And if roads of this most desirable type are to be satisfactorily and cheaply maintained, it will be more than ever necessary to study routes in relation to the rocks that are traversed and the water contained in them.

Something of what has been said with reference to roads applies with equal force to other engineering undertakings, railways, and canals, harbor-works, bridges, and large and heavy buildings, particularly those intended to stand for centuries. The general success of such works is ample testimony to the knowledge and skill expended upon them by engineers and architects, as well as to the elastic toleration of sites so heavily taxed; and one is tempted to believe that a much larger amount of study has been given to geological questions in these cases than is usually admitted.

Water.—Of all engineering questions, that most closely involved with geological science is probably water supply. So far as underground water is concerned, geologists and engineers working together have amassed a volume of fact and principle which has not yet been completely codified and rendered accessible. An unexpectedly large proportion of the available rainfall has in many instances been obtained by successful drilling, in spite of the complication of the question by surface pollution, and in the face of many legal inanities and much charlatanry. And the extension of these methods to arid regions, as in Australia and north Africa, has brought under cultivation large areas which needed nothing but the "striking of the rock by the rod" of the driller to make new oases in the desert, and thus render available some of the richest soils in the world.

Much the same is true of overground supplies, which have been a blessing not merely to the towns and lands supplied, but to the rivers and drainage basins regularized and protected in large measure from ever-recurrent floods and the damage consequent upon them. Although in such works geological conditions are often taken

into full account, an elaborate geological survey at a very early stage would in most cases more than pay its way. Such a survey would not only give a good preliminary idea of the nature and tectonics of the rocks underlying sites of dams and reservoirs, but it would save its cost in limiting the number and in giving rational direction to the inevitable pits which must be sunk, by restricting them to the elucidation of points which the surface mapping leaves obscure. It would at the same time direct attention to the innumerable pitfalls which sites often present and would generally provide on the spot much of the requisite material for construction.

It is an arguable question whether the expenditure of such vast sums as have been devoted to the supply of large towns is entirely justified. The provision of a single supply, of which large quantities are used for drinking, cooking, and industrial purposes, necessitates that the water shall be of immaculate purity, and this pure substance, the purest of all the things we consume, is employed—may we not say wasted—for flushing, washing, and a host of other purposes for which a less pure water would suffice. Surely the time has come when people could be educated up to the use of a dual supply, and this should be a commercial possibility where the area served and quantity used are really large. The experience of London has shown the very high cost of a single supply to all consumers and for all purposes, and the limits of future supply are almost in sight. It seems to be time that the problems of a dual service should engage serious attention.

Power.—Owing to the configuration and rainfall of the British Isles, and their congested population, we are apt to think of water questions in terms of supply, and, though we are using a certain amount of water for power, there is only a limited development possible. In many other parts of the Empire, however, this is becoming a valuable asset, and nowhere more than in Canada, which is rapidly developing its resources on a very large scale. What has been said with reference to water supply is of equal application here, for the physiographic conditions which bring about steep gradients accompanied by large bodies of water, introduce factors of denudation, transport, and deposition by the water which call for most careful selection of sites for reservoirs and works, if the all too frequent disasters are to be avoided, and if the schemes are not to be ephemeral in duration and excessively costly in upkeep.

With sources of power other than coal and water—including that of the tides—the geologist has little concern. But there has been brought into service at Volterra, in Italy, a new source of power in the high-temperature steam from fumaroles which had previously

been used only as a source of borax. Now the steam is being tapped by borings adventurously carried out, and its chief heat is employed in running great power stations, only the residual heat being given up to the manufacture of borax. This may be but the beginning of the application of a new and valuable source of power in which the services of geology will be required and from which that science stands to learn much. We are haunted by the fear that a limit will be imposed by high temperature to deep mining, while that very heat may provide energy as valuable as the material which would otherwise be mined; just as we dread the gas from certain coal seams when the gas might, if it could be exploited, give a return equivalent to that of the coal itself.

Agriculture and Forestry.—Leaving aside relations already touched upon, the connection of geology with agriculture and forestry is through the medium of soils and subsoils, and, though the geologist seems unsuited to deal unaided with soils, his methods are those which the soil investigator must use; and soil surveys are now being carried out by agriculturists working in conjunction with geologists. This results in giving new and valuable facts and inferences for the benefit of both sciences. On the geological side it is rendering more available the facts of plant distribution, and what has been called agronomics, which, speaking for myself, I have always found very hard to get hold of. On the other hand, the services of geologists are likely to be of especial value in the matter of tranported soils, loams, loess, brick earths, drifts, gravels, and the like, where the conditions of formation may in many cases provide a key to their peculiarities. The same considerations apply to forestry, and here, in addition, well-established facts, such as the successive forest types displayed in peat bogs, may betray principles that will be of service in practice. Questions of site, sewage-disposal, and health are bound up with questions of water and agriculture and need no further notice here.

Military Science.—It will be readily admitted that geology has been of conspicuous service in connection with military operations in such ways as the siting of camps, trenches, and dug-outs; while the minute study of the water table in northern France during the late war was not only of value in obtaining water supplies but was of conspicuous utility in mining and countermining, in which exact and detailed knowledge was successfully pitted against a knowledge which was "just there or thereabouts."

The "eye for a country," the visualizing of features plotted on maps and making the utmost use of them, qualities on which good strategy is founded, are the same qualities which are essential to a competent geological surveyor; and I can not help thinking that

strategic ability would reap as much advantage from a knowledge of the underlying canons of topographic relief as the geologist would from a study of the principles of military topography. It was a wise scheme to train the British home and overseas armies on ground similar in kind and in relief to that on which they were about to fight in France; but it should have been realized that physical causes and the resultant topographical relief differ in essential particulars in temperate and tropical climates.

INTELLECTUAL SERVICE

Innumerable as are the services which the science of geology has rendered to man on the material side, these are at least equalled, if not outweighed, by those rendered on the intellectual side, either in the direct application of its principles to the life of mankind, or in the aid given to other sciences and the confidence engendered in such of their conclusions as can be tested in the light of geological history.

Throughout most of its range and in its more special directions, geology, like zoology and botany, is mainly an observational science. Multitudes of facts have to be observed and grouped, and as much skill is required in selecting from them the more significant and decisive as in collecting them. Experiment for the most part is of service in the criticism and verification of tentative theories; and, on the physical and applied sides more especially, it is becoming of great value. But the process of examination in chief, and the cross-examination in the field by a highly qualified and fully trained observer, are so exhaustive that not very much is left to submit for checking to the experimenter.

Even more than either of these two sciences is geology an open-air science and one which calls for and imparts a love of nature that can not but deepen as knowledge increases. Its most interesting work lies as a rule in the districts most attractive for other reasons. In the course of geological work the country must be thoroughly traversed, and, when possible, should be seen again and again, in all lights, under all aspects, and at all times and seasons. Hypotheses grow but slowly, and call for constant checking or verification in the field, the gradually growing ideas being an intensive spur in the collection of new facts or the reobservation of old ones, and in the comparison with like or unlike cases published or unpublished. But, as they grow, hypotheses give to their framer a power of prediction, more precise as the hypothesis is better founded; and one of the most fascinating parts of his work is the testing out of such predictions and the making of crucial observa-

tions thus needed and inspired. It is for these reasons principally that geology has earned its reputation as a fighting science. It is hard to decide just exactly when evidence amounts to absolute proof; and different observers, having reached varying stages in the completeness of their observations, may be led by the sum of them to different explanatory theories; or in the sphere of their own work they may be specially influenced by facts current there.

This seems to be the place to enter a protest against dominant ideas with regard to education and training in geology. The tendency in early education has been to squeeze out other sciences in favor of those that are called fundamental, and to suppose that, because it makes use of most other sciences, training in geology ought not to be begun until all others have been mastered. This is to go counter to the history of the science itself. Its leading methods were evolved in the early days of physics and chemistry and by men often ignorant even of such principles as were then understood. As geology has grown it has given to these sciences many problems for solution in return for the solutions received, problems which would have long waited for attention had not their geological application been urgent. Further, as the solution of his problems requires not only a very extensive knowledge, but a workmanlike ability to apply both methods and principles, it is difficult to say at what stage even the most competent scientific man, if he is ultimately to deal with all his problems himself, can be ready to begin the study of geology.

Meantime, qualities of far higher value to a geologist, which in most cases can only be acquired young, are being lost, such as the habit of close observation, the aptitude to distinguish minute resemblances and differences, and the faculty of judging tendencies, together with the instinct and patience to make collections. These propensities come very early and speedily become blunted if not exercised. I would advocate, with all the earnestness of an old teacher, that some form of earth-knowledge involving observation of facts and collection of specimens, and the drawing of inferences from them, should find a place in schools and be encouraged at the universities side by side with the fundamental sciences. Such studies will not possess the meticulous exactitude of the others, but in this respect their tendency may be corrected by them. They will, however, bring the student into contact with realities, things as they are, instead of inaccessible, abstract conceptions, things beyond experience—such as pure substances, or forces acting in the absence of friction. They will give him the thrill of discovery and explanation, teach him that the end of science is to extract law and principle from observation and experiment, and, instead

of keeping him along rigid lines to an assured and preobtained solution, will give him a choice of approach and accustom him to frame and test hypotheses which to him at any rate will be new and his own. Further, they will do much to teach him his own shortcomings and give him a keen incentive to acquire the very sciences which in themselves may be dull or even repulsive until he has convinced himself of their utility and necessity to his own work.

While acknowledging indebtedness to those sciences which have so generously contributed their results to geology, we feel that we have some ground for complaint that at times their votaries have not resisted the temptation to drop bombs which have exploded in our midst and produced a certain amount of trepidation and sometimes legitimate indignation. We consider that it is up to those who feel compelled to do this to acquire some knowledge of geological principles and of the lines of reasoning on which they are founded. They should recognize that a pyramid is difficult to upset, because in the process of building it the materials and structure have been carefully selected and tested by the builders. To be told after a century's search and reasoning that we must take our time bill and "sit down quickly and write" off 80, or it may be 90, per cent of it, ought not to have disturbed us as much as it did, not more indeed than now does the permission of the representatives of the same science to multiply our original time bill, if we like, by 10 or 20, or even more, so far as their present state of knowledge extends. Our answer is that we have not done the one and have no desire to do the other, so far as the sedimentary rocks at present known to us are concerned.

The geologist, however, should be, and is, the last to deprecate the application of the highest and newest conclusions of physical and chemical science to his own problems and to the criticism of his solutions of them, for it is certain that this will always result in doing much to reduce many of the barriers which retard his advance. For this reason we must welcome even so fantastic a hypothesis as that of Wegener, for the problem of the overthrust "nappes" of mountain regions is one of our greatest difficulties, and all explanations hitherto proposed are so hopelessly inadequate that we have sometimes felt compelled to doubt whether the facts really are as stated.

But the phenomena have now been observed so carefully and in so many different districts that any real doubt as to the facts is out of the question, and we must still look for some adequate method by which the overthrusting could have been brought about. And if dozens of square miles of ground have been shifted over their foundations and away from their roots for many linear miles in the course

of a single geological Period, who shall say what might not be accomplished in the course of Eras?

Important consequences flow from the fact that the goal and expression of most geological research is the construction of a map of the area studied. To the layman who studies a country with a geological map in hand, it is hard to resist the conclusion that the map is merely fanciful; he can see no evidence for the lines laid down or the symbols employed, and he is astonished when trenching or drilling proves their correctness at any particular point. It is difficult for him to see or to realize the cumulative force of the aggregation of minute pieces of evidence, slight differences in slope or soil, variations in quality, quantity, or luxuriance of vegetation, variations in dryness or moisture, the distribution of culture, the extension into the area of some underlying tectonic plan—the laws of which may have been worked out elsewhere—and the thousand-and-one considerations which go to make up the mind of the geologist.

It is, of course, perfectly true that the individuality of the surveyor enters not a little into the extrapolation of geological lines, beyond the points where direct observation of the rocks is possible. So much is this the case, that it is feasible, from the inspection of his map, to gauge, not only the geological competence, experience, and attainments of the surveyor, but his knowledge and grasp of physiographic form, his power to see into intricate solid geometry, his artistic skill of hand and eye, and, above all, that indefinable quality his "eye for a country" on which so very much depends.

The construction of a map has the further advantage that it grows by the alternation of periods of observation in the field with periods devoted to the thinking out of structure after each day's work and in the intervals between successive visits to the field, so that with every return to the ground, the facts may be reobserved and lines retested in the light of growing knowledge. It is true that ideal observation should be so complete and exact that reobservation has nothing to teach; but, as a matter of fact, with a map as with a book, what one takes from it is what one brings to it, clarified, improved, and extended. There should be allowed to professional geological surveyors as much elasticity as possible, so that, in addition to detailed and exhaustive primary survey, there may be frequent revision in the light of their own work and that of their neighbors. In this respect the hand-colored form in which geological maps were originally published has an advantage over the newer, cheaper, and more consistent color-printed maps.

Geologists should give a cordial welcome to the new aid provided by aerial survey and photography. This provides the last point of view of their areas, which has been hitherto denied, though they

have been in the habit of making use of the only substitute open to them, prospecting and photographing from the highest points accessible. Many unexpected results have thus been secured in archeology, and at least as much may be looked for in geological surveys even in settled and surveyed districts, while in unsurveyed and unprospected regions its use is proving of the highest importance. Too much credit can not be given to Canada for its enterprise in using this method for the prospecting and preliminary survey of the animal, vegetable, and mineral resources of its great hinterland by means of the airplane. A great saving in time and cost has thus been secured, and the method bids fair to remove the reproach leveled at the British Empire that such vast areas of it are practically unknown.

Physiography and Geography.—It is because of the variety and intensity of observation essential to geological surveying—in the course of which every acre of his ground must be traversed, and much of it retraversed—that the geologist must necessarily become a physiographer and geographer. There is a limit to the perfection of topographic maps and surveys, even when, as in the United States, there is close cooperation between the Topographic and the Geological Surveys; and it is the duty of the geologist to take note of innumerable features which have no delineation, still less explanation, on such maps. The geologist is probably the only class of person who has to traverse large areas with his eyes open, not to one class of phenomena only, but to all that can help him to decide questions of concealed structure; and he naturally seeks to supplement this by personal contact with the inhabitants, and with their written and unwritten records, which it is part of his business to interpret and explain. Nor can he confine himself to the purely physiographic aspect of his area. He is led into bypaths as a byplay, and many facts with regard to the distribution of animals and plants, and of the dwellings, occupations, and characteristics of the people, can scarcely escape his observation; neither can he shut his eyes to historic and prehistoric facts. Thus, when a geologist leaves his district, he is generally possessed of a store of knowledge reaching far beyond the strict bounds of his science.

While geologists, from the conditions under which they work, have been able personally to make individual contributions to these sciences, the most important service of geology as a whole has been the transformation of geography from a static into a dynamic science. In its earlier stages, geology discovered that progress involved the close study of the earth of the present and the application of that knowledge to explain its past changes; and the progress of geology has only intensified both the need of deeper study and the

fuller application of it. To-day it is essential for geographers to be perfectly familiar with the past history of the earth in order that they may be able to explain the phenomena of the present.

The question may be summed up by saying that geology has become a physiological study of the earth as an organism with a life all its own. We can watch the geographical changes through which the earth has passed, revealed as they are in the nature and distribution of rocks and fossils. We can even discover the dry land—the actual landscape and physiographic relief itself—preserved in a fossil state, and judge from it the climates then prevailing and their distribution in distinct epochs. We can form some idea of the modes of origin and dates of appearance of continents and mountain chains, and other leading features of the relief of the crust. We are learning to read the evidence given by the interactions of igneous and aqueous rocks as to the nature of the stresses by which the structure of the crust itself has been moulded. There are, it is true, many gaps in our knowledge, but their very existence is of value in quickening and directing research in order that our history may become as full as it can possibly be made. Each advance upon the technical side of the subject, the pursuit of detailed zonal stratigraphy, the application of the miscroscope in so many new directions, and the broadening of the area of study, all react sooner or later in improving, refining, and extending our knowledge of earth history. They combine with the evidence of paleontology to convince us that this earth of ours is still young, active, and full of life, and that any process of "running down" is constantly being held by self-acting checks which are putting forward to vastly distant ages "all prospect of an end."

Biological sciences.—While astronomy has given us the conception of illimitable space, it has done much to destroy what has been called the anthropomorphic view of creation. Geology, on the other hand has endowed us with an almost limitless conception of time, but it has done something to rehabilitate the importance of man as the highest product yet reached in the long history of the earth.

This it has done in the main through the intense reality that it has given to the conception of evolution. Although several authors, and two in particular, have pointed out that such a conception could not have been formed without the postulates of time and continuity of existence contributed by geology, it is hardly realized how much geological labor on the life of the earth, and on life on the earth, as summed up by Lyell and grouped and presented by him in his great work on "The Principles of Geology," was necessary to give to evolution a concrete and cogent application. The function of this labor could hardly be better indicated than by the position of geology as displayed in Lyell's earlier editions. The modern reader of them

is continually haunted by the feeling that the author was struggling for a single missing generalization which he failed to find; and although, in almost every branch of the subject treated, Lyell leads up again and again to the missing conception, and though the facts and inferences which he marshalled can now be seen to be marching on this great idea, he never quite succeeded in attaining it for himself. It was left for Darwin, than whom no one was more conscious of what he owed to Lyell, to see that the facts must rest on some great single fundamental principle, to realize that this principle was evolution, and to apply it to his own branch, the development of life.

Lyell had proved that the long history of the earth as recorded in the rocks revealed the operation of causes, small in relation to the earth as a whole, but persistent, the majority of them still in action. It was a further debt to Lyell that Darwin should bring in the continuous operation of small causes as the machinery operating and guiding the evolution of life.

But though the work of geologists, as summed up by Lyell, provided the starting point for the conception of organic evolution, it did not stop here. The idea of Uniformitarianism in which that work culminated was meant as a reaction against the fantastic operations postulated by the Catastrophists, and was never intended to imply that these causes in the past were always balanced or distributed as they are now. There was in Lyell's statements nothing to indicate that denudation or earth movement might not have been more active at periods of the past, that organic change might not accelerate or slow down, that there might not be variations in the trends of continental or oceanic development resulting in climatal and other changes, or that the very sources and intensities of energy from outside or inside the earth might not seriously vary. Only, warrant must be found for all such suppositions with regard to the earth of the past from fuller study of the earth of the present. And if we recognize the inner spirit which inspired the eloquent words of Lyell, when he had grasped that Darwin had supplied the one missing idea, we can not fail to see that his Uniformitarianism included evolution as one of the "existing causes" to be taken into consideration.

The physiology of the earth, however, is that of a very complex organism, and we are sure that we do not yet know all the forces internal and external acting upon it, still less their relative value and intensity, their distribution and variation in the past, or the precise records which each is capable of imprinting on the rocks of the earth-crust. But it is becoming clearer that there has been a periodicity in the stages of development of the earth crust, and that on these great pulses of earth life there have been imposed innumerable waves of

smaller cycles; and that, on account of their interference with, or reinforcement of, one another, the simpler type of cyclic repetition which might have been looked for in the history is masked and broken and diversified by actual happenings of an infinite variety.

Van Hise more than once complained of the tendency of geologists to adhere to single explanations of events, and advocated the necessity of considering the cooperation of many causes; and it may well be that in many outstanding problems such as past glacial or tropical periods, coral reefs, stages of earth movement, progression and regression of the oceans, we may find the ultimate explanation in the interaction of a number of "true causes."

EVOLUTION

During the long period of time comprised in the history from the Cambrian period onwards, the slow and persistent evolution of plant and animal life went forward and left ample record in the rocks. To warrant a belief in organic evolution, we are no longer solely dependent on reasoning founded on existing organisms or on the facts of their ontogeny and distribution. As M. Marcellin Boule says in his work on Fossil Man, "* * * pour tout ce qui a trait à l'évolution des êtres organisés en général, le dernier mot doit rester à la Paléontologie quand cette science est en measure de parler clairement. Les plus fins travaux anatomiques, les comparaisons les plus approfondies, les raisonnements les plus ingénieux sur la morphologie des êtres actuels ne sauraient avoir la valeur démonstrative des documents tirés de la roche où ils sont enfouis et disposés dans leur ordre chronologique même."[2] Although we are only too painfully aware of the innumerable chances that conspire to prevent an animal or plant from securing immortality by preservation as a fossil, the finding of better preserved material, the more skillful preparation of it for examination, and the application to it of refined biological methods, such as careful dissection and the serial sections of Professor Sollas, are giving us more complete and accurate knowledge than ever before. It may now be confidently stated that many of the most crucial links in the chain of evolving life are in our hands; that they actually lived in the past, and that their fossil forms show their relationship to their predecessors and successors. The time has come when Darwin's famous chapter on the "Imperfection of the Geological Record," an apology written with the most balanced criticism and unbiased judgment, should be rewritten and revised.

It is true that we seem as far as ever from unveiling the points of divergence of the great phyla, and we can but feel that the time from the beginning of the Cambrian period onward is but a small part of

[2] Marcellin Boule, Les Hommes Fossiles, 1923, p. 453.

the whole history of life on the earth. As with antiquarian research, each new discovery in geology, whether on the physical or the biological side, only brings these distant ages more fully into view and emphasizes their modernity and their likeness to our own time. Hutton's famous dictum that he saw "no vestige of a beginning, no prospect of an end," is to-day more true than ever, when we regard the evidence of stratified rocks. But we know enough to convince us that within post-Cambrian time evolution has steadily proceeded from general to special, from simple to complex, from lower to higher efficiency.

In almost every subdivision of the animal kingdom, and in not a few branches of the vegetable kingdom, lines of descent and directions of specialization have been made out, sometimes visibly operating throughout whole Systems, but more usually through smaller divisions of the record; and this in the former kingdom not only among vertebrates but among the invertebrates and even their lower subkingdoms. It may even be stated that in methods of defense, in food procuring, in the attainment of favorable positions and attitudes, something very closely imitating what would be expected on the doctrine of the origin of species by "survival of the fittest" has again and again occurred.

The essence of evolution is unbroken sequence, and when we consider the extraordinary delicacy of the adjustment of life to its physical and organic environment, the mutual interdependence of life forms, and the necessity to them of such factors as favorable range of temperature, food, climatic conditions, soil, and the continuity of the "element" in or on which they live, it is most wonderful that in the vast lapse of post-Archaean time it has been possible for life to exist continuously and continually to evolve, throughout those long ages. And this in spite of the fact that, although the main chain has been unbroken, conditions have, in many cases, been so unfavorable that whole groups have flourished and died out, while others have become so attenuated that only a few survivors have been left, highly restricted in distribution, to burgeon out again when the unfavorable conditions were removed, or in other places where conditions have again become more favorable to them.

That life has survived continuously in spite of the vicissitudes through which it has been compelled to pass, and the frequent convergence upon it of unfavorable conditions, may well be taken to heart by those who fear that civilization will be brought to an end by the misuse of the powers that itself has evolved. They may surely take courage and trust that the remedy for these evils will come, as it has in innumerable other cases, not from conventions

and understandings that, as all history shows, will be mere scraps of paper, but from the intensive application to them of the very science which has evolved them.

Although the geological record is, and possibly will always remain, incomplete, it has yet proved remarkably representative, and certain outstanding facts have been made out which are sufficient to show that the lines of organic evolution as recorded in geology are in accordance with what is theoretically probable, and with those taken by the evolution of domesticated organisms and by human arts and inventions.

1. There can be no doubt that the stages of organic evolution are correlated with and were actuated by the stages in the inorganic evolution of the earth itself. That climatic change was effective in inducing migration, and thus in sharpening the struggle for existence against both enemy organisms and changed physical environment; that extension and restriction of land and water areas in some cases brought about keener and more varied competition, change of habit or food, and in others the destruction of potential enemies and the securing of the advantages of a fair field for the survivors; and that activity of the earth-crust in such things as deposition and mountain building provided conditions for the existence of an increased range of varieties and the consequent struggle between them: If we are not allowed to say that this brought about the survival of the fit, it at least caused the destruction of the unfit.

2. It may be stated as a biological law that every locality becomes "full" of life, forms arriving or evolving to take advantage of the special facilities offered. In consequence, resistance to the incursion of new forms, even if they are exceptionally equipped, is very great, and it is only occasionally that such new forms can make good their immigration. There are, of course, marked exceptions, but these generally occur when degeneration or overgrowth in size accompanied by neglect of means of defense have occurred, or when an area has been for so long sheltered from the wider and more general course of evolution that it has fallen seriously behindhand in the race.

The geological record gives indirect evidence of the same "filling" of areas in the past in the extraordinary slowness with which advanced types that have eventually made great headway established themselves after their introduction; the earliest fishes, reptiles, and mammals are cases in point. Imperfect as the first members of these groups undoubtedly were, they must, even shortly after their introduction, have possessed considerable advantages over the older and established forms with which they found themselves in competition. In size and strength they were doubtless

inferior, and probably they must have taken long periods to make good their advantage. But in all such cases the new forms went for a long period into "retreat," and, in face of the apparent slowness of their evolution and the bitter competition to which they were subjected, it is remarkable that they overpassed the troubles of racial youth, and eventually took the place to which they were entitled in the scheme of life. It seems justifiable to believe that there must have been at least some well-equipped types which did not survive competition in these early stages, but went under with all their promise of future success. We can easily imagine that the survival of such, had it occurred, may have altered the whole course of evolution and produced a life-story very different from that we know to-day, and of which we ourselves form no small part.

3. Not less remarkable than the period of "retreat" is that of booming development which at last came to each successful modification. In this connection we can instance the "pleine évolution" of the graptolites, the euechinoids, ammonoids, and belemnoids, the fishes, reptiles, birds, and mammals, each in its own time. Each slowly but surely built up its supremacy, and then wantoned through long ages as the lord of creation in its own element and in its own day. Both the period of sanctuary and the subsequent boom can be closely paralleled by the case of many human inventions and in the occupations and history of mankind.

4. But while there are outstanding cases in which a line of advance is taken that is capable of successive improvements and leads on to continuous success, there are many other instances in which the line of advance, though temporarily advantageous, has only been carried through a limited number of stages, and eventually failed either by its inherent inadequacy or by imposing so heavy a burden on the economy of the organism that it was unable to bear the cost.

The only instance I need quote, though there are many others, is the use of defensive armor, spines, plates, hooks, horns, etc. These provide an obvious method of resistance to attack, and this defensive attitude has been practised by one group of organisms after another, but always with the same disastrous result, the imposition of a fatal strain on the organism to meet renewed, perfected, and more vigorous attack. The spinose graptolites and trilobites, the armored fishes and reptiles, are cases in point, and in the last of these instances, at least, victory rested with the acquirement of swiftness in movement, accompanied by increasing power of attack such as is given by the development of teeth or claws or both. Again and again in the Tertiary Era one group of mammals after another, before, or more usually after, the attainment of great size,

has taken to some means of sedentary defense, and in every case the cost of upkeep has been too great and the group has gone under. Every time the race has been to the swift, active, and strong, and those that trusted in "passive resistance," in "defence and not defiance," have gone under in competition with those that have been prepared to face the risks involved in attack. The fact that turtles and armadillos have survived to the present indorses rather than vitiates the principle.

Other cases of rapid decline or sudden disappearance are more difficult to account for. The waning of the brachiopods, but not yet their disappearance, the disappearance of the pteridosperms, the rugose corals, the belemnoids and ammonoids synchronizing with the vanishing of many orders of reptiles, will long furnish subjects for research by biologists and geologists.

And it may well be that the explanation will often be along biological rather than physical lines, such as those suggested for the graptolites; Lapworth pointed out that their disappearance—in spite of a brave effort of passive resistance—synchronized with the great development of fishes, and the assumption by them of many of the functions previously discharged by the trilobites. In other cases the explanation may be more in the direction of that given for the reptiles, to be referred to later.

The rarity in the geological record of some of the stages in evolution, and the absence of others which must surely have existed, may receive some explanation from what has frequently occurred in the history of human invention. If variants arise and are subjected to intense competition, they have no chance in the struggle for existence unless they show rapid improvement and development of the favorable variations within a few generations. Hence the numbers exhibiting each of the early stages of change will always be few and the chances of their preservation slight. Those who have tried to work out the stages in the history of an invention, for instance, will appreciate the rarity of "missing links" and the difficulty of filling in every step toward the later perfection. These are looked upon as "freaks" and, unless they present real and marked improvement, are never manufactured on a large scale. Their numbers consequently are few, and many of them are the victims of experiment and often do not survive the experience.

5. Perhaps the most wonderful result disclosed by a study of the later part of the geological record is the steady and unbroken evolution of brain from the earliest vertebrate animals to the present. The exceeding slowness of the process in its early stages is not less wonderful than its acceleration during the latest stages of geological history. The disappearance of so many orders of reptiles at the end

of the Mesozoic period, at the close of a long and most promising chain of evolution, indicates that there was some inherent weakness underlying the line of evolution entered upon by them, which proceeded so far and favorably that it was impossible to retrace the path. This may well have been connected with the substance or construction of brain and nerve. If so, this side of evolution has to be seriously reckoned with, and it may be that the fundamental weakness of physical as opposed to intellectual evolution brought this flourishing and well-developed group to its end.

It has, of course been suggested by Searles V. Wood, jr.,[3] and others that the destruction of Mesozoic life types was brought about by physical changes; but, apart from the fact that the particular changes supposed by the former did not as a matter of fact occur, the entire explanation provides a cause utterly insufficient in comparison with the potency of organic struggle against creatures better endowed with warm blood, adequate brain substance, and the activity and enterprise springing therefrom.

In spite of the evidence of acceleration as the higher ranks of animals are reached, and in spite of the extraordinary efficiency of the human brain and all the benefits to the organism it brings about, we may well be appalled by the aeons which have been used up and the millions of varieties which have passed away in the production of this, the most efficient scientific apparatus yet invented or evolved.

6. But if it has taken long ages to evolve an animal capable of a broader geographical distribution than any other, with a constitution capable of withstanding the widest ranges of heat and cold, and of peopling the world from its tropical deserts to its polar wastes; and to endow him with a brain by virtue of which he has made himself master of the earth and all its living inhabitants; it has taken no less time for the evolution of the many factors without which his present success would have been impossible. To pick out a single instance, probably few things in the whole story of life have been more fruitful in effect than the appearance of the grasses in late Eocene times, followed by their rapid evolution and spread in the Oligocene and under the direction of the critical events of the Miocene period. Starkie Gardner, in an admirable paper, first drew attention to the vital importance to the animal evolution of the world in general, and to the welfare of man in particular, of this step forward. It was followed by great changes in the insect world, by the rapid production of herbivorous mammals endowed with speed, great migratory powers, special dental and other anatomical

[3] Phil. Mag., Vol. XXIII, 1862.

adjustment to the new foods, and the institution in their herds of a discipline, subordination, and leadership which are almost tribal. These last qualities were rendered doubly necessary by the consequent rapid development of carnivora, and the need for scrapping passive and even active means of defense in order to secure the power, speed, and reserve necessary to follow their food harvests over great stretches of country. At the same time the habits and instincts thus brought about were those which man, by domestication, has been able to turn to his own ends. Thus at a blow, as the outcome of this stage of Tertiary evolution, there became available for mankind not only his chief plant food and drink, his luxuries as well as his necessaries, but his chief animal foods, together with his aid from the speed, strength, service, and endurance of the animals which he domesticated, and to which he assumed the position of leader of the herd.

But while with the aid just described it was possible for mankind to progress far on the road of civilization, progress would have been stopped, and as a matter of fact was seriously retarded, until the discovery and utilization of the solar energy stored up in the earth's crust during the Carboniferous and subsequent Periods in the form of coal and other fossil fuels. The very exceptional conditions, climatal, geographical, and botanical, requisite for coal formation, occurred all too seldom in geological history, but it has so happened that few areas of the earth are devoid of coal belonging to one Period or another; and the shaping of kingdoms and dominions has been such as to include supplies of fuel in most of them.

Whatever may be the main sources of energy in the future, radiant, intratelluric, hydraulic, tidal, atomic, we have been largely dependent in the past, and probably shall continue to depend for many years to come, on that portion of the solar energy stored up by vegetation, and especially on that preserved in the earth crust in the form of coal.

But again civilization must have been greatly hampered or driven into a different course but for the agencies which have sorted out from the medley of materials of which the earth is composed, simple compounds or aggregates of compounds, or in rarer cases simple elements, in such a form that they are available for human use without the expenditure on them of excessive quantities of energy. The concentration of metalliferous ores, salines, and the host of other mineral resources has made perhaps the most important contribution of all to the latest stage—in good and evil—attained by civilization.

Finally, doubt may be expressed whether man could have attained his present position if he had not made his appearance comparatively soon after a period of intense earth activity, when broad areas

of newly raised sediment were available for occupation, when the agents of denudation and renewal were in vigorous operation, and when a wave of rapid organic evolution was active. And a conjecture may be permitted that human evolution itself was probably hastened by the latest climatal severity through which the earth passed, the effects of which are only slowly passing away.

Much of what has just been said may revive recollection of an old Swiss guide book which praised the beneficence of Providence in directing the dreaded avalanches "into the desolate and uninhabited valley of the Trumleten Thal and in sheltering from them the beautiful, fertile, and inhabited valley of Lauterbrunnen." However, it is far from my intention to imply that "everything is for the best in this best of all possible worlds," but only to point out in reviewing the long chain of events of which we see the present end-product in civilized man, that within the ken of the geologist there have been many critical stages in the earth's history when any marked change in the conditions which then prevailed must inevitably have reacted profoundly upon the development of the human race when at long last it stepped out from the lower ranks to take the earth as its rightful possession.

CONCLUSION

A review of the history and present position of geology shows that its better-known services to mankind have been in relation to the foundations on which industrial development and modern civilization have been built—the mineral resources of the earth. These are many and various, all of them explored by geological methods. In every application of them we are again brought back to the primal essentials—water, iron, and fuel—and it is in the discovery and exploitation of these that the services of geology have been of especial value.

But in the course of the development of both the economic and the scientific sides of geology the principles discovered and elaborated have fertilized and enriched human thought as expressed, not only in other sciences but also in the sphere of literature. As it has become more precise and is able to give a more accurate and detailed picture of the stages through which the earth passed during the long story unfolded by the study of the stratified rocks, it has shown that the earth, though only a minute fraction of the visible universe, has had a wonderful and individual history of its own. The keynote of this history is evolution, the dream of philosophers from the earliest times, now passed from the realm of hypothesis into that of established theory.

We are able to watch the evolution of the oceans and continents, of the distribution of landscape and climates, and of the long succession of living beings on the earth, throughout many millions of years. During these ages we see the action of the same chemical and physical laws as are now in operation, modified perhaps in scale or scope, producing geographical and biological results comparable with those of to-day. Hutton and Lyell discovered for us in the present a key to unlock the secrets of the past; the history thus revealed illuminates and explains many of the phenomena of the present.

And the outcome of it all is to endow man with a simple and worthy conception of the story of creation, and to fill him with reverence for the wondrous scheme which, unrolling through the ages, without haste, without rest, has prepared the world for man's dominion and made him fit and able to occupy it.

I desire to express my thanks to Mr. G. W. Lamplugh, Professor E. W. MacBride, Professor W. G. Fearnsides, and Mr. G. S. Sweeting for kind assistance in the preparation of this address.

THE YEASTS: A CHAPTER IN MICROSCOPICAL SCIENCE[1]

By A. Chaston Chapman, F. R. S., F. I. C., F. C. S., P. R. M. S.

The subject on which I have the honor to address you this evening is intimately connected with phenomena in which mankind has taken a very deep interest from time immemorial.

It is not my intention to deal with the antiquity of alcoholic fermentation, except just to say that references to the use of fermented beverages by ancient peoples, such as the Chinese and Egyptians, chiefly in connection with religious and ceremonial observances, appear to date back more than 4,000 years, and in the Vedic books—the oldest literary monuments of the Indo-European races—there are many references to intoxicating beverages.

The word "fermentation," from *fervere*, to boil or seethe, was at first applied to all cases of chemical change whose cause was unknown, and which were accompanied by the formation of large quantities of gas, giving the liquid the appearance of boiling or seething. In its widest sense the word is still occasionally applied to a number of chemical processes in which micro-organisms are the active agents, such, for example, as the souring of milk, the conversion of alcohol into vinegar, the production of butyric acid, and similar processes. In its restricted sense, however, and in the sense in which I shall use it this evening, it is applied to the conversion of sugar into (mainly) alcohol and carbon dioxide gas by means of the organism known as yeast.

The subject of fermentation is capable of rough division into two parts—namely, the phenomenon, that is to say, the process, and the origin or cause of that phenomenon—yeast.

With fermentation regarded as a chemical process I do not propose to deal, beyond referring very briefly to a few of the earlier attempts made to explain an occurrence which was characterized by so much that was mysterious. The word "fermentation" is very frequently met with in writings of the alchemists from the thirteenth to the fifteenth centuries, but it is applied to a considerable number of chemical processes of all descriptions, and the ideas

[1] Address of the President of the Royal Microscopical Society, read Jan. 21, 1925. Reprinted by permission from the Journal of the Royal Microscopical Society, March, 1925.

of the writers were vague and confused in the extreme. Perhaps the first philosophical explanations put forward were those of the German philosopher, Stahl (1660–1734) and of the English physician, Thomas Willis, who described himself as "of Christ Church in Oxford, and Sidley Professor of Natural Philosophy in that famous University." According to their view, fermentation is considered to be an induced action—that is to say, the ferment is a body endowed with a particular molecular motion, which motion is, by induction, communicated to other bodies with which it may be in contact, thus bringing about their decomposition. Thus, Willis in his tract, "De Fermentatione" (1660), says: "Fermentation is the internal motion of particles, or of the principles of a body, either tending to the perfection of the same body, or its change into another. * * * There are many methods by which fermentation may be induced. The first, the chief one, is the adding of a certain ferment to the body to be fermented, the particles of which being first placed in vigour and motion, may arouse the other sluggish and idle particles in the mass that is to be fermented, and may drive them into motion. * * * By this means Barm or Yest, beaten eggs and such like, stir up a fermentation almost in everything." But in spite of the clearness of these statements, Willis, like the other philosophers of his time, included putrefaction, the formation of minerals in the earth, and a vast number of other natural phenomena under the general term "fermentation."

The next important attempt to explain the nature of fermentation was made in 1839, when the great German chemist, Liebig, put forward a theory which was a modification of that of Stahl and Willis. Liebig asserted that nitrogenous matter on oxidation underwent a change which determined the breaking up of the molecules of fermentable matter in contact with it, and laid considerable emphasis on the importance of the presence of oxygen. This theory of contact decomposition as the result of molecular vibration held the field for more than 30 years, but during the latter part of its life it was vigorously attacked by Pasteur, who was then engaged upon his epoch-making biochemical researches. The controversy was a long and vigorous one, and in the end Liebig modified his original views to the extent of admitting that the fermentation process was in some way connected with the life activity of the organism producing it, but he adhered so far to his earlier view as to hold that this life activity was not in itself the exciting cause, but was only necessary for the formation of some protein like substance which actually brought about the decomposition. This theory, which was put forward shortly before his

death in 1873, is of special interest in connection with the view which is now universally held as the result of comparatively recent observations.

I will now turn to a discussion of the nature of the investigations which have led up to our knowledge of the character and life history of the exciting cause of fermentation—that is to say, of the yeast organism—and for this purpose it will be necessary for me to take you back nearly 200 years from Liebig's day. Although the phenomena of fermentation had been a matter of common observation for many centuries, it is obvious that no successful attempt could have been made to arrive at a knowledge of the originating cause until the microscope had been sufficiently developed for the purpose. The first examination of yeast itself of which we have any record was made by the great Dutch microscopist, Leeuwenhoek, in 1680.

At this stage, and before dealing with the actual results of Leeuwenhoek's observations, it may be of interest to some members of the society if I refer in some little detail to the instruments employed by one who may justly be regarded as one of the greatest microscopists of all times. The following description by Martin Folkes, published in the Philosophical Transactions of the Royal Society in the year 1723, contains much that is historically of great interest, and something that may not be well known to all who are present this evening.

Mr. Folkes says:

It is now above fifty years since the late Mr. Leeuwenhoek first began his correspondence with the Royal Society, when he was recommended by Dr Regnerus de Graaf as a person already considerable by his microscopical discoveries made with glasses contrived by himself, and excelling even those of the famous Eustachio Divini, so much talk'd of in the learned world; and as he has ever since that time apply'd himself with the greatest diligence and success to the same sort of observations, no doubt can be made of the excellency of those instruments he so long use'd, so much improv'd, and upon the fullest experience so often commended in his letters; great part of which at his decease he thought fit to bequeath to this society, for whom he ever express'd the greatest esteem and respect. He had indeed intimated this design in several of his letters, and in his last will and testament gave orders that the glasses should be deliver'd as soon as conveniently might be after his decease; which was accordingly done by the directions of his surviving daughter, Mrs. Maria van Leeuwenhoek, to whose great care we are oblig'd for the safe and speedy delivery of this very curious and valuable present.

The legacy consists of a small Indian cabinet, in the drawers of which are thirteen little boxes or cases, each containing two microscopes handsomely fitted up in silver, all which, not only the glasses but also the apparatus for managing of them, were made with his own hands; besides which they seem to have been put in order in the cabinet by himself as he design'd them to be presented to the Royal Society, each microscope having had an object placed before it, and the whole being accompany'd with a register of the same in his own hand-

writing, as being desirous the gentlemen of the society should without trouble be enabled to examine many of those objects on which he had made the most considerable discoveries.

Several of these objects yet remain before the microscopes, tho' the greater number are broken off, which was probably done by the shaking of the boxes in the carriage. I have nevertheless added a translation of the register, as it may serve to give a juster idea of what Mr. Leeuwenhoek design's by this legacy; and also be of use, by putting any curious observer in mind of a number of minute subjects that may in a particular manner deserve his attention.

Then follows a list of the objects, which may conveniently be omitted.

For the construction of these instruments it is the same in them all, and the apparatus is very simple and convenient; they are all single microscopes consisting each of a very small double convex glass let into a socket between two silver plates rivetted together and pierc'd with a small hole; the object is placed on a silver point or needle, which by means of screws of the same metal provided for that purpose, may be turn'd about, rais'd, or depress'd, and brought nearer or put farther from the glass as the eye of the observer, the nature of the object, and the convenient examination of its several parts may require.

Mr. Leeuwenhoek fix'd his objects if they were solid to this silver point with glew; and when they were fluid or of such a nature as not to be commodiously view'd unless spread upon glass, he first fitted them on a little plate of talk, or excessively thin blown glass, which he afterwards glewed to the needle in the same manner as his other objects.

The observation indeed of the circulation of the blood, and some others, require a somewhat different apparatus, and such a one he had, to which he occasionally fix'd the same microscopes; but as it makes no part of this cabinet, I shall omit giving any farther account of it, only taking notice that it may be seen in a letter to the Royal Society of the 12th of January, 1689, and printed in his Arcana naturae Detecta, No. 69. But I was willing to mention just so much as it may serve to shew the universal use of these microscopes, and as it induces me, among other things, to believe, these were the kind of microscopes generally, if not solely, us'd by this curious gentleman in all his observations, and to which we are oblig'd for his most surprizing discoveries.

Another particular to the same purpose, I would not omit, and that is, that upon the late queen Mary's doing Mr. Leeuwenhoek the honour of a visit at Delft, and viewing his curiosities with great satisfaction, he presented her with a couple of his microscopes, which as I have been inform'd by one who had them a considerable time in his hands were of the same sort as these, and did not any ways differ from one of the 13 cases contain'd in the drawers of this cabinet.

The glasses are all exceedingly clear, and shew the object very bright and distinct, which must be owing to the great care this gentleman took in the choice of his glass, his exactness in giving it the true figure; and afterwards amongst many, reserving such only for his use, as he upon tryal found to be most excellent. Their powers of magnifying are different, as different sorts of objects may require; and, as on the one hand, being all ground glasses, none of them are so small, and consequently magnify to so great a degree, as some of those drops frequently us'd in other microscopes; yet on the other, the

distinctness of these very much exceeds what I have met with in the glasses of that sort; and this was what Mr. Leeuwenhoek ever principally propos'd to himself, rejecting all those degrees of magnifying in which he could not so well obtain that end; for he informs us in one of his letters where he is speaking of the excessive praise some give to their glasses on this account, that although he had above forty years had glasses by him of an extraordinary smallness, he had made but very little use of them; as having found in a long course of experience, that the most considerable discoveries were to be made with such glasses as magnifying but moderately, exhibited the object with the most perfect brightness and distinction.

But however excellent these glasses may be judg'd, Mr. Leeuwenhoek's discoveries are not entirely to be imputed to their goodness only: his own great judgment and experience in the manner of using them, together with the continual application he gave to that business, and the indefatigable industry with which he contemplated often and long upon the same subject viewing it under many and different circumstances, cannot but have enabled him to form better judgments of the nature of his objects, and see farther into their constitution, than it can be imagined any other person can do, that neither has the experience, nor has taken the pains this curious author had so long done.

Nor ought we to forget a piece of skill, in which he very particularly excell'd, which was that of preparing his objects in the best manner, to be view'd by the microscope; and of this I am persuaded any one will be satisfied, who shall apply himself to the examination of some of the same objects as do yet remain before these glasses; at least, I have my self found so much difficulty in this particular, as to observe a very sensible difference between the appearances of the same object, when apply'd by my self, and when prepared by Mr. Leeuwenhoek, though view'd with glasses of the very same goodness.

I have the rather insisted upon this, as it may be a caution to us, that we do not rashly condemn any of this gentleman's observations, though even with his own glasses we should not immediately be able to verify them our selves. We are under very great disadvantages for want of the experience he had, and he has himself put us in mind more than once, that those who are the best skill'd in the use of magnifying-glasses may be misled, if they give too sudden a judgment upon what they see, or 'till they have been assured from repeated experiments. But we have seen so many, and those of his most surprizing discoveries, so perfectly confirm'd by great numbers of the most curious and judicious observers, that there can surely be no reason to distrust his accuracy in those others, which have not yet been so frequently or carefully examin'd.

Upon the whole, it is to be hoped some of the society will pursue those enquiries the late possessor of these microscopes was so deservedly famous for; and that as we have lost in Mr. Leeuwenhoek a most worthy member and a most valuable correspondent, this last piece of his respect to the Royal Society will not only enrich our repository but both encourage and enable some other diligent observer to prosecute the same curious and useful discoveries.

Unhappily the microscopes bequeathed to the Royal Society by Leeuwenhoek have ceased to enrich its repository, since, when the society removed to its present habitation, the miscroscopes disappeared in a very mysterious manner, and their whereabouts—if indeed they still exist—has not been traced, even to the present day.

That the Royal Society were appreciative of Leeuwenhoek's great services to science is shown by the fact that in 1679 a certain Mr. Hunt was "instructed to prepare a silver box for the diploma to be sent to Mr. Leeuwenhoek."

In 1680 Leeuwenhoek addressed to the Royal Society a communication headed "De Fermento Cerevisiae," in which he announced that he had discovered that yeast consisted of small ovoid globules. Of these, which he appeared to regard as consisting chiefly of batches of six, he gives several excellent drawings. When we remember the nature of the magnifying apparatus with which he had to work, and that the average diameter of the yeast-cell is only $\frac{1}{120}$ millimeter ($\frac{1}{3000}$ inch), it will, I think, be realized that Leeuwenhoek had accomplished a very remarkable feat. He did not, however, push the discovery any further, and in this position, curiously enough, the matter remained for more than a century.

In the year 1814 Kieser, in the course of a paper by Döbereiner, described yeast as consisting of small spherical corpuscles, but this statement does not appear to have attracted attention, and about the year 1837 the microscopical character of yeast was again made the subject of investigation, and the true nature of the yeast organism was definitely and independently discovered by three observers, Cagniard de Latour, Schwann, and Kützing. These observers recognized that yeast is composed of a vast number of small transparent globules which reproduce by budding and which consist of a cell wall with granular contents. A year or two later Schwann appears also to have observed the formation of ascospores. These observers, and Cagniard de Latour in especial, put forward the view that it was owing to the vegetation of these cells that the disengagement of carbon dioxide gas and the formation of alcohol were due. The researches of these observers having shown that yeast consisted of a lowly vegetable organism, capable of reproducing by budding, the question arose, how was yeast originally formed, and around this subject, as is well known, a fierce scientific controversy raged, the Heterogenesists, on the one hand, upholding the doctrine of spontaneous generation, and the Biogenesists, on the other hand, asserting that all life must be derived from preexisting life. With this aspect of the matter, and with this controversy I do not propose on this occasion to deal, and it will suffice perhaps to say that the rigid experiments of Pasteur succeeded in proving to the satisfaction of practically the whole scientific world that every yeast cell was derived from a preexisting cell of the same kind, and that the doctrine of spontaneous generation was not based upon any foundation of fact.

The microscope having definitely shown yeast to consist of minute living cells—that is to say, of a living organism—it became of high interest and importance to study its life history, and to ascertain what connection, if any, there was between the vital functions of the organism and the phenomena of fermentation. It was very quickly recognized that yeast usually reproduced by budding, but in 1839 Schwann appears to have observed for the first time that it was also capable of reproducing by the formation of ascospores.

About the year 1856 Pasteur commenced his epoch-making researches on fermentation, and brought to bear on the subject that experimental skill and wonderful energy which were characteristic of all his work. To deal with this in any detail would be impossible within the limits assigned to a presidential address, and would, moreover, take me outside the scope of my subject. It will, however, suffice for my purpose if I point out that to Pasteur belongs the honor of having definitely enunciated a physiological theory of fermentation—that is to say, a theory which associated the formation of the various fermentation products directly with the life activity of the yeast organism. It is true that in some important respects his views have had to undergo modification as the result of more recent work, but the essential fact still remains that the production of alcohol and carbon dioxide during the process of fermentation is indirectly the result of the life activity of the yeast cell.

In 1897 Buchner made the very important and interesting observation that the liquid contents of the yeast cell, when added to a fermentable liquid, are able to excite fermentation without the presence of any cells at all. He showed that the production of alcohol and carbon dioxide were the result of the activity of an enzyme secreted by the cell, to which he gave the name zymase. As in the case of other enzymes, zymase is very sensitive to external conditions, and is also highly selective in respect of its chemical activities. Thus, so far as is known, the hexoses alone, and of these, only four (d-glucose, d-mannose, d-galactose, and d-fructose) are directly fermentable; and before the fermentation of other sugars, such as maltose and cane sugar, can take place, it is necessary that they should be converted into one or other of these hexoses. This is, in all cases, effected by enzymes which are secreted by the yeast, and it is very interesting to note that certain yeasts, while secreting invertase, and therefore capable of fermenting cane sugar, do not secrete maltase, and are therefore incapable of fermenting maltose. Then again, there are a few yeasts which, in addition to secreting invertase and maltase, secrete lactase, and are therefore capable of fermenting milk sugar. Every yeast cell is, in fact, a minute laboratory in which chemical changes of the utmost complexity are

brought about with apparently the greatest ease, and where processes of building up and breaking down are carried out in a manner of which even to-day we have but very little conception.

We will now turn for a moment to the consideration of yeast as a living organism.

The yeasts, as is well known, belong to the great family of the fungi, and may be described as unicellular fungi, reproducing by budding, and capable also of forming ascospores. This latter function is of importance from the point of view of classification, as it serves to differentiate between what are regarded as the true yeasts and certain other closely allied organisms, such as the torulæ and mycoderma. In the common process of budding, the bud, which occurs first as a small protuberance on the surface of the cell, quickly increases in size until it has attained roughly the dimensions of the parent cell, after which it usually becomes detached, leading a separate existence, and reproducing in turn by the same process. It often happens that before the offspring cell has separated from the parent cell it has itself commenced to bud, and so chains or clusters of connected cells may frequently be seen.

In the second mode of reproduction to which reference is made above, the yeast cell becomes changed into an asc, in which are formed a number of spores which may vary from one to as many as twelve, but is usually from two to four. The conditions which favor this mode of reproduction are the employment of young and vigorous cells, a moist surface, plenty of air, and a suitable temperature, usually about 25° C. Under these conditions, and at the end of about 24 hours, certain changes will be seen to be taking place in the protoplasmic contents of many of the cells, especially the more vigorous ones. The protoplasm becomes at first very granular, and then signs of segregation become visible, the contents of the cell separating into a number of ill-defined portions, usually from 2 to 4, but in some species as many as 8 or 12. A little later each of these segregated portions of highly granular protoplasm becomes invested with a membrane, and it can then be seen that the cell contains a number of well-defined spores. During the formation and development of the spores the parent cell often swells considerably, and in the end bursts, liberating the spores, each of which constitutes an individual yeast cell, and is capable of reproducing in the ordinary way by budding. It may be added that the line between budding and ascospore formation is not very sharp, and that it often happens that budding and sporulation may be taking place simultaneously. As a general rule the spores are spherical, but in some of the yeasts they have very characteristic forms. It would seem that spore formation

is a provision on the part of nature for securing the persistence of the species under conditions in which active budding is impossible. It appears, at any rate, to play an important part in the hibernation of yeasts, rendering it possible for them to live through the winter in the soil, or on surfaces from which very little nutriment can be extracted.

In addition to reproducing by budding and by ascospore formation, yeasts are capable of reproducing by still a third method, namely, that of true conjugation. In these yeasts, constituting the genus *Zygosaccharomyces*, certain of the cells form, instead of ordinary buds, long beak-like processes. When the "beaks" of two adjacent cells touch one another a union takes place, the tips of the "beaks" disappear, and a tubular connection is established between the two cells, one or both of which then proceed to produce ascospores. Of these conjugating yeasts a number of different species have been described, and this sexual process in one form or another appears to be much more common than was until recently supposed.

Finally, there is a group of organisms, usually included among the *Saccharomycetes*, which are capable of reproducing by the process of fission. In these so-called *Schizosaccharomycetes* the fission of the cell, often accompanied by conjugation, is preceded by the formation of a septum, which at once commences to divide into two lamellæ. Budding does not occur, but the cells form spores, usually from two to eight. It will be seen, therefore, that in the great family of the yeasts many types of reproduction are exhibited—from true conjugation (heterogamic and isogamic) in the case of some, through isogamic conjugation of ascospores formed in the same asc, in others, to complete parthenogenesis, as in the case of many of the better known cultivated yeasts. The industrial yeasts, which appear to be entirely asexual, may perhaps be regarded as retrograde forms descended from higher types in which sexuality was quite clearly marked. On this point I do not consider myself qualified to express an opinion.

As may well be supposed, in the case of a group of organisms which, although presenting some very important differences, are yet so closely allied, and in which there are very many transitional forms, a great deal of confusion exists in respect of their classification. The system at present generally adopted is one based upon that suggested by Hansen in 1904, but it is customary to include the *Schizosaccharomycetes* which he excluded, and there has been, of course, a natural tendency to include a number of subdivisions. The great family of the *Saccharomycetes* is capable of being subdivided into a number of groups or genera, each of which in turn includes a number of species, considerably more than 100 of which have been described.

I will not attempt to deal with these various genera in any detail, but it may be of interest just to give some indication of the general nature of the principles underlying one of the systems of classification, which differs, however, in some respects from that of Hansen. According to this, yeasts may be divided into five main groups. The first group includes the *Schizosaccharomycetes*, characterized as I have indicated above by their method of reproducing by transverse division. The asci often result from isogamic conjugation, and as a rule from four to eight ascospores are formed.

The second group, or *Zygosaccharomycetes*, consists of yeasts in which conjugation of a more or less well-marked character is connected with the formation of the asc. This may, perhaps, be a very primitive group, and one from which, possibly, the parthenogenic yeasts have been in process of time derived. This group has been divided into a number of genera, depending on the precise character of the conjugation process.

The third group comprises all those yeasts which reproduce mainly by budding, and in which the formation of the asc is not, so far as is known, preceded by any process of conjugation. This group, which has been subdivided into several genera, comprises the true *Saccharomycetes*—that is to say, the alcohol-producing yeasts of industry.

The fourth group, which includes the genera *Pichia* and *Willia*, comprises yeasts which do not exhibit any trace of sexuality, and which usually develop in the form of a film or skin upon the surface of the liquids in which they happen to be growing. These organisms do not, as a rule, produce any appreciable quantity of alcohol, but some of them give rise to the production of fruity ethers. Finally, there is a fifth group, including two or three genera, consisting of organisms whose connection with the *Saccharomycetes* is somewhat doubtful.

From what I have said it will have been gathered that the division of the yeasts into a number of more or less well-defined genera has been based almost entirely upon differences in their morphological and physiological characters. For the further differentiation into species it was found necessary, in many cases, to adopt other methods of investigation, such as the behavior of the yeasts toward certain selected carbohydrates, and observations on the optimum conditions required for the formation of ascospores and of films.

With regard to the first point, on which I have already touched, it has, for example, been found possible to subdivide the genus *Saccharomyces*—which is included in the third of the main groups

to which I have referred above—into five subgroups, each of which again is capable of subdivision into a considerable number of well-defined species.

With regard to film formation, this again is a character of considerable importance in connection with the differentiation of species. As I have indicated, certain of the yeasts—especially those included in the fourth of the main groups above referred to—grow normally on the surface of nutrient liquids, forming dry greasy films, and producing, as a rule, little or no alcohol. It is not, however, of such films as these that I am now speaking. Although the true *Saccharomycetes* do not readily exhibit the phenomenon of film formation, yet under proper conditions this is capable of being brought about. In order to obtain films, the culture, in wort for example, must be allowed to remain at rest for a considerable time with an abundance of air, and at warm room temperatures. Under these circumstances small specks of yeast will generally appear on the surface of the liquid some considerable time after the actual fermentation has come to an end. These gradually coalesce, forming isolated patches of different forms and sizes, and, finally, these patches unite to form a continuous and generally glutinous film which may extend to the walls of the vessel. A study of the time and temperature factors involved in the formation of these films affords, as I have indicated, one method of distinguishing between certain yeast species. So far as the purely morphological differences are concerned, it was observed at a comparatively early period that the yeasts exhibited considerable differences in shape, some being spherical or ovoid, whilst others were decidedly ellipsoidal, and others, again, elongated and sausage-shaped. On the other hand, in one and the same species very great differences in shape and size were frequently noticed, depending upon the general environment and growth conditions of the organism. No great advance, therefore, could be made in differentiating between the various species until Hansen, in 1879, devised and explained the technique for obtaining any quantity of yeast by starting with a single cell. In this way absolutely pure cultures could be obtained, and the uncertainty which had previously existed was removed.

Of the very large number of yeast species known, it may be said at once that only a comparatively few are of industrial importance, and it is customary to divide the various yeast species for technical purposes into the "cultivated" and the "wild" yeasts. The former include brewers' and distillers' yeast in all its varieties—that is to say, yeast which has from the earliest times been used for the pro-

duction of alcoholic beverages, and has in a sense been cultivated for the purpose. This yeast represents, as far as is known, one species—namely, *Saccharomyces cerevisiæ*—although there are many races and varieties which differ considerably in certain respects, as, for instance, in the rapidity with which they bring about fermentation, the degree of attenuation which they can effect, and the flavor of the finished product.

The "wild" yeasts are yeasts which occur wild in nature, frequently having their habitat on the surface of ripe fruits, and often finding their way into the brewery. Some of these yeasts, such as the wine yeasts, are capable of fulfilling useful functions; others again are, so far as is known, without effect good or bad; whilst others are industrially pathogenic—that is to say, give rise to products which are unpleasant in respect of flavor or smell or which exhibit some other defect, such as pronounced and persistent turbidity.

The importance of these observations in connection with industrial fermentation processes may easily be imagined. Prior to the isolation and study of the various yeast species, and to the microscopical control to which it naturally led, industrial fermentations were very largely a matter of chance. Sometimes the results were good, sometimes they were bad, but none could say precisely why. Now all that is changed, and when it is remembered that the industrialist who is concerned with any fermentation process is threatened on all sides by intruding organisms which may have the effect of reducing his yields or spoiling his products, the need for scientific control, and for the constant employment of the microscope will be evident.

I now propose to turn for a few minutes to a consideration of the cytology, or, if I may be permitted the expression, the anatomy of the yeast cell. For a great many years after yeast had been subjected to microscopical examination there was much uncertainty as to whether the cell did or did not contain a true nucleus. Although the existence of a nucleus is now well established, there is still some doubt as to the precise nature—to say nothing of the functions—of certain of the internal structures which the microscope reveals. Wager and Peniston, Guilliermond, Fuhrmann, Henneberg, Meyer, and others have published important papers dealing with the cytology of the yeast cell, and have shown that it possesses a well-defined and complex internal structure.

According to Wager and Peniston the main vacuole is to be regarded as the nucleus, and they consider that this is the structure which is chiefly concerned in the promotion of metabolism, whilst

the deeply staining structure in close contact with it, and which is generally regarded as the nucleus, is to be looked upon as the nucleolus. This is a view in which I have never felt myself able to concur, although much, of course, depends on the precise meaning given to the words *nucleus* and *nucleolus*, respectively.

In addition to the nucleus with a clearly differentiated structure and a nucleolus, the cell contains cytoplasm. a chondrium, metachromatic granules, a nuclear and other vacuoles, and certain thread-like structures. The cell wall, about which a good deal of uncertainty exists, appears to consist as a rule of a single membrane, and to have a complex chemical composition.

In addition to these elements, which may be regarded to some extent as structural, there exist in the cytoplasm accumulations of materials concerned in the nutrition or metabolism of the cell, such, for example, as glycogen and fat.

With regard to the functions of these various cell elements it is not yet possible to speak with very great certainty. As in all cells the nucleus is the main seat, or rather the directing organ, of the physiological functions of the cell. It is all important in cellular reproduction and division; it plays apparently a prominent part in nutrition, and doubtless in it reside the properties which are hereditary, and in virtue of which one species may be distinguished from another. The chondrium, consisting of two forms of mitochondria, appears to be concerned in processes of nutritional elaboration, and the nuclear or main vacuole appears to be largely concerned with metabolic processes, and is according to some observers the seat of fermentative activity. This latter function has, moreover, been observed to be dependent on the amount of metachromatic granules contained in the cell, the larger the amount of metachromatin (volutin) the greater the fermentative activity; and Henneberg has gone so far as to suggest that the metachromatic granules may be the parent substance from which the enzyme zymase is derived. From this necessarily brief and sketchy account of the yeast-cell anatomy it will at least be gathered that our knowledge is very imperfect and that we have much to learn, and it may be hoped that some of the expert cytologists who are members of our Society may be induced to turn their attention to the elucidation of the subject. There can, I think, be very little doubt that the results would be of important industrial as well as of purely biological value.

The ordinary microscopical examination of cells which have been subjected to the drastic processes of fixing and staining obviously has its limitations, and modifications of structure, such as must almost inevitably be brought about by the above processes, may very

easily give rise to incorrect conclusions in regard to the internal structure of such a delicate organism as the yeast cell. It would almost appear, in fact, that we have gone as far as it is possible to go in this direction, and some improved method of investigation will have to be resorted to if many of the questions which are at present in doubt are to be satisfactorily solved. It is possible, for instance, that a very careful microscopical study of the unstained cell by means of ultra-violet light may be helpful in giving us a better insight into its internal structure, and Mr. Barnard has already carried out some interesting experiments of a preliminary character in this direction.

When one remembers that the whole of a miniature solar system is comprised within the compass of an atom, it is not, perhaps, altogether fanciful to suppose that the yeast cell—small as it is—may have a much more highly developed internal organization than has been revealed with our present imperfect means of investigation, and that there may be more or less distinct localization of the different functions of the cell. In this connection two sets of facts may be briefly referred to.

In the first place, it is well known that the yeast cell, like other living organisms, may be made to perform different functions according to the conditions under which it is compelled to carry out its activities. Thus, whilst the ordinary *Saccharomyces cerevisiæ* normally decomposes sugar with the production of alcohol and carbon dioxide, and only about 3 per cent of glycerine, it has been found that when the fermentation is conducted in the presence of a considerable quantity of sodium sulphite the main products of the fermentation consist of acetaldehyde and glycerine in roughly equal molecular proportions, and that instead of the normal 3 per cent as much as 36 per cent of glycerine can be produced. In other words, it would appear that the well-known equation representing fermentation, viz:

$$\underset{}{C_6H_{12}O_6} = \underset{\text{alcohol}}{2C_2H_6O} + 2CO_2$$

has, when the process is carried out in the presence of sulphite, to be written in the following very different and unfamiliar form,

$$\underset{}{C_6H_{12}O_6} = \underset{\text{acetaldehyde}}{CH_3COH} + CO_2 + \underset{\text{glycerine}}{C_3H_8O_3}$$

In the next place, it is of considerable interest to note that the behavior of the enzymes within the cell appears to differ materially from that of the same enzymes in the expressed juice. Thus, the

acceleration of fermentation by the addition of aldehydes is much greater in the expressed yeast juice than in the case of the living cell, and there are other respects in which the actions proceeding in the juice differ from those occurring within the cell. This seems to suggest that the mechanism of fermentation is in some way directly connected with the organized structure of the cell. In the living cell, again, the velocity of fermentation is much greater than in the expressed juice, and it would seem that in its natural surroundings within the cell zymase is free to act without the disturbing influences which probably exist in the expressed juice where all the cell contents are mingled, and some substances may well interfere with the activity of others.

Cramer (Proc. Roy. Soc., 1915, 88, B, 584) has dealt with this important and interesting point, and has shown that the most striking difference between the action of enzymes within the living cells and their action after extraction is the extreme sensitiveness with which, in the former case, they respond to very slight changes in the surrounding medium, being sometimes retarded, sometimes accelerated, and sometimes reversed. According to Cramer surface tension would appear to be an important factor, such surface tension being operative, for example, at the periphery of the cell and at the boundaries of the nucleus, vacuoles, granules, colloidal aggregates, etc. Thus the conditions for enzyme action may be very different in one part of the cells from those occurring in another part. Under the influence of very slight changes in external conditions there may, for example, take place within the cell a movement of the cytoplasm, or changes in the concentration of the cell constituents which, by altering the surface tension at different parts, may altogether change the conditions for enzymic action. Even assuming Cramer's explanation to be correct, it still means that the great variations in the physiological and chemical activities of the cell are dependent on internal structure, and it is to this problem that future research may usefully be directed. Any great increase in our knowledge of this subject might prove to be of the highest importance, not merely in regard to industrial operations, but as affording a deeper insight than we yet possess into the true character of the vital activities of the living cell. It may be hoped that our society, which has done so much to direct and foster the study of microscopical science, may figure prominently in connection with an investigation, the results of which might well prove to be of fundamental importance. In the living cell we have, in fact, a chemical laboratory of the highest efficiency, and of the most re-

markable character; and could we but understand and imitate artificially the processes of building up and breaking down which are so quietly and so regularly occurring in a single cell of yeast, we should be not only within measurable distance of a new organic chemistry, but also we should be appreciably nearer to an understanding of that greatest of all problems, the nature of life.

TROPICAL CYCLONES AND THE DISPERSAL OF LIFE FROM ISLAND TO ISLAND IN THE PACIFIC[1]

By Prof. Stephen Sargent Visher
Indiana University

EVIDENCE FOR AND AGAINST A PACIFIC CONTINENT

One of the mooted questions concerning the Pacific is how the biota now found upon the scattered islands got there. There are two great schools of thought in respect to the matter. One believes that the presence of numerous Asiatic forms can only be explained on the assumption that at some earlier time many of the now remote islands were connected into a continent. Some members of this school think that the continent extended as far as the Low Archipelago and Hawaii.[2] Others do not ask for so much land, but assume a southeastward extension of Asia, to include the East Indies, Philippines, New Caledonia, Fiji, and Samoa. Certain large islands are also believed to have existed, for example, one that would include all the Hawaiian Islands and another that would unite the Cook, Austral, Society, and Tuamotu islands.[3]

The other school of thought is opposed to the idea of a Pacific continent, or of vast islands in it, and to the extension of Asia and Australia beyond New Caledonia.[4] They contend that the agencies distributing life from island to island are sufficiently efficient to have enabled the land forms to spread to the remote islands upon which they are found.

However, there are several features of the distribution of land forms that are difficult to explain on the basis of prevailing winds and ocean currents. One is the fact that many of the forms of even the easternmost islands are related to Asiatic forms rather than to American forms. That is not true of all types of life; a

[1] Reprinted by permission from The American Naturalist, Vol. LIX, January–February, 1925.

[2] Campbell, Douglass H., "Some botanical and environmental aspects of Hawaii," Ecology, Vol. I, pp. 257–269, 1920; Bryan, Wm. A., "Hawaiian fauna and flora," Proceedings First Pan Pacific Scientific Conference, Vol. 1, p. 158, Honolulu, 1921; Scharff, R. F., "Distribution and Origin of Life in America." 1911.

[3] Pilsbry, H. A., "The dispersal and affinities of Polynesian land snails," Proc. Pan-Pacific Scientific Conf., Vol. I, pp. 147–151, 1921.

[4] Many geologists and biologists belong to this school, including T. C. Chamberlin, C. Schuchert, H. E. Gregory, D. S. Jordan, F. Muir, etc.

considerable number of Hawaiian forms, for example, being derived from a few American ancestors. Many of the seed plants, birds, and some insects were derived from Central American ancestors.[5] But a large enough percentage of the forms are so Asiatic as to have led those scientists who have examined this particular type of evidence to doubt if the existing distribution can be explained on the basis of existing conditions. They have shown, for example, that a favorable wind (the prevailing trades) and current (the drift set in motion by the trades) should have given Hawaii many Californian and Mexican forms of littoral mollusca, if these agencies were effective in transporting these forms.[6] Likewise, the believers in the theory of widespread lands and certain other workers point out that the prevailing winds and currents throughout the Pacific tropics are westward, and the numerous species of Asiatic descent must have advanced eastward against the prevailing winds and currents. Yet the wind and currents are the only important agencies, aside from man, that might have transported the plants and animals in question from island to island.

HOW HURRICANES CAN DISTRIBUTE LIFE

Is it not highly probable that tropical cyclones have played a part in the dispersal of life from island to island in the Pacific? Upon their equatorward side there are often violent westerly winds, completely overcoming the prevailing easterlies. As pointed out in discussions of the courses followed, many storms move eastward, within the tropics, or just beyond the tropics.[7] In moving eastward, the strong westerly wind on its equatorward side carries much with it, and sets up a strong drift as well. An illustration of the occasional power and persistence of this westerly wind is given by the renowned missionary John Williams, who, driven by cannibals from Hervey Island, drifted in an open boat 500 miles to Tahiti with a constant westerly wind.[8] Normally, easterlies prevail in that portion of the ocean.

The power of the wind to transport light objects through the air is frequently illustrated during hurricanes, as, for example, when land birds and insects are carried out to sea in large numbers. Indeed, the presence of butterflies and birds far out at sea has

[5] Brown, F. B. H., "Origin of Hawaiian flora," Proceedings First Pan-Pacific Scientific Conference, vol. 1, pp. 131–142, 1920 (seed plants); Muir, F., "Some problems in Hawaiian entomology" (insects), ibid., and Henshaw, "Fauna Hawaiiensis," volume vertebrates (birds).

[6] Muir, F., loc. cit.

[7] Visher, S. S., "Tropical cyclones of the Pacific with charts of tracks," Monthly Weather Review, Vol. 50, pp. 288–297, 583–589, 1922, and Bulletin 20 of Bishop Museum of Honolulu, 1925.

[8] Williams, John, "Missionary Enterprises in the South Sea Islands," London, 1838.

often been mentioned in connection with hurricanes. A specific case of interest is mentioned by Dr. F. Woods-Jones [9] concerning insects at Cocos-Keeling Island in the Indian Ocean. During a severe northwesterly wind associated with a hurricane, hundreds of dragonflies were driven the 700 miles from Sumatra and Java, the nearest land, to this little island. However, as the island possessed no suitable environment for dragonflies the introduction was ineffectual in spite of the large numbers driven there. But if a marsh or other favorable environment for these insects should develop on the island, there is no question that within a short time some storm wind would stock it with dragonflies.

An actual increase of the permanent fauna of Cocos-Keeling Island took place during Doctor Wood-Jones's residence there, shortly after they had added a new plant, tomatoes grown from seed. At first the tomatoes had no enemies, but before the first crop was ripened an insect pest was brought by the same cyclonic gale that brought the dragon flies from Java and Sumatra. Although Cocos-Keeling Island is in the belt of trades, which blow with exceptional strength and persistence from Australia, almost no Australian species are found in the fauna. Doctor Woods-Jones believes this fact is an illustration of Alfred Russell Wallace's generalization that flying forms are rather well adjusted to the prevailing winds, just as aquatic forms living in a regular current commonly are adjusted to it so as not to be swept away. But the sudden, irregular, violent winds and currents sometimes associated with tropical cyclones take many individuals by surprise and carry them away from land.

Not only are animals with wings sometimes carried long distances by hurricane winds, but many forms attached to leaves are thus carried. The stripping off of almost all the leaves occasionally accomplished by hurricanes has been mentioned often. Some of these leaves are carried far, and on these parachutes are sometimes attached worms, larvæ eggs, or small snails.[10]

HURRICANE CURRENTS AS DISPERSING AGENCIES

The strength of the abnormal ocean currents set in motion by hurricane winds is mentioned repeatedly in the Pacific Islands Pilot.[11] The significance of such abnormal currents may be illustrated by a statement concerning the Hawaiian Islands. A few years ago the mangrove was introduced upon the island of Molokai.

[9] Professor at Adelaide University, Australia. Remarks following my paper before the Royal Society of New South Wales, November, 1921.

[10] Pilsbry, H. A., "The dispersal and affinities of Polynesian land snail faunas," Proc. First Pan-Pacific Scientific Conference, vol. 1, p. 149, Honolulu, 1921.

[11] U. S. Hydrographic Office, Washington, 1920.

In spite of strong normal currents at right angles to the favorable direction, seeds are occasionally floated to Oahu by abnormal currents, and the tree is now establishing itself there, more than 25 miles from Molokai.[12]

The facts that most of the lowland plants and animals of the wide stretch from Fiji and the Carolines to the Low Archipelago and Hawaii are of the same or closely allied species, and that at the same time there is a progressive dropping out of species eastward, suggest strongly that the distribution of life forms has been from scattered island to island and has been accomplished by transporting agencies that are rather efficient, though not perfectly so. The fact that relatively few forms are of American origin (except remotely) suggests the inadequacy of the normal trade winds and normal currents as agencies of dispersal, in accord with Wallace's law concerning normal winds and currents. However, the relatively small part that South America has played in supplying forms to the Pacific Islands doubtless is due partly to two special conditions. One is found in the few islands in the eastern part of the tropical Pacific. Indeed, good atlases show no islands between the Low Archipelago and South America, about 3,000 miles away. The Galapagos Islands, on the Equator, are almost the only islands north of that zone in similar longitudes. South of 24° S. latitude are only Easter Island (28° S.), Sala-y-Gomez (26½° S.), and a few other islets or rocks to the west and northwest of Easter Island, and also San Felix and Juan Fernandez Islands near the eightieth meridian, not very far from South America.

The second special condition highly unfavorable to the spread of South American forms over the Pacific Islands is the fact that much of the western portion of tropical South America is almost barren of life, on account of the extreme aridity of the lowlands and the presence of the lofty Andes only a short distance from the coast. Somewhat similar conditions obtain over a wide belt in the North Pacific. There are almost no islands between Hawaii and North America, and most of the coast of Mexico is almost barren on account of aridity. On the other hand, the southeastern coast of Asia and the East Indies teem with forms adapted to the climatic and soil conditions which obtain in most of the Pacific Islands.

Another argument of advocates of great extensions of the lands is the following: They say that wind and currents, even those associated with hurricanes, apparently are not effective in the dispersal of certain types of life, as shown by the absence from the coast of

[12] Oral communication by C. S. Judd, Territorial forester. Several illustrations of the significance of changes in ocean currents in the Atlantic are given in papers in the Proceedings of the First Pan-Pacific Scientific Conference, vols. 1 and 2.

Queensland of certain forms known in New Caledonia. Both the normal trades and numerous hurricanes pass over New Caledonia and thence to Queensland, and yet the coconut is established at only a few points on the Queensland coast, and certain species of land snails abundant in New Caledonia are unknown in Queensland.

The general lack of the coconut in Queensland appears not to be due, however, to a lack of seed there, for they are often noticed sprouting along the shore. The severe droughts during the cooler season of each year, characteristic of this part of Australia, may be the factor preventing their widespread establishment on this coast.

The absence from Queensland of the large showy land snail (*Placostylus*), common on the islands to the eastward, may be due to the presence in Australia of enemies that prevent their establishment. The Australian bush turkey feeds upon similar Mollusca, and it has been suggested by Curator Charles Hedley, of the Australian Museum, as possibly responsible for the absence of this island snail in Queensland.

HURRICANE FLOODS AND LIFE DISPERSAL

Another way in which hurricanes have influenced the dispersal of land forms is in connection with the floods they cause, whenever excessive amounts of rain fall in a short time. There are numerous records of the fall of more than 10 inches in two days, and some records of more than 60 inches in three days.[13] Under such conditions normally rather small streams become rivers and carry to sea vast quantities of driftwood. The river banks are eroded badly, and many trees are undercut and carried out to sea. During the excessive rains, large masses of dirt and loose rock upon steep hillsides often slip or slump, sometimes temporarily damming valleys. In case the dam breaks, the sudden rush of waters does its part to contribute natural rafts of driftwood, with their load of land animals and seeds. Furthermore, the animals are not nearly so likely to be picked off a raft by sea gulls or other birds during a hurricane as they are in ordinary weather. Hence, the absence of long rivers flowing into the Pacific, with the exception of the Chinese rivers, should not lead to the assumption that natural rafts of considerable size and biological dispersing possibilities are lacking in the Pacific.[14]

[13] Visher, S .S., "Tropical climates from an ecological viewpoint," Ecology, Vol. IV, pp. 1–10, 1923, and "Tropical cyclones of the Pacific," Bull. 20, Bishop Museum, Honolulu, 1925.

[14] Pilsbry, H. A., (loc. cit.) has made this erroneous assumption. He states: "The argument for distribution of animals by natural rafts has never been more convincingly stated than by W. D. Matthews in his paper 'Climate and evolution.' Much of his argument, however, is not applicable to the Pacific islands. Here we have no large rivers to give forth natural rafts. If a single tree is washed to sea it must be very exceptional."

Tropical cyclones have also played a part in the distribution of peoples over the Pacific. Legendary accounts indicate that a number of island groups were discovered by occupants of boats that had been blown out of their course by storms. The discovery of New Zealand by Polynesians en route from Samoa to the Cook Islands is a specific illustration.[15]

MAN AS AN AGENCY OF DISPERSAL

The great importance of man in distributing plants and animals of economic importance and, incidentally and inadvertently, of numerous smaller species concealed in the soil or bark or on leaves has been emphasized by several scientists.[16]

GEOLOGIC CHANGES

The dispersal of life from island to island over the Pacific has been accomplished slowly. Undoubtedly, during the geologic ages, there have been geologic changes that have been significant. For example, it is known that long ago there was more than once a strait where the continuous Central America now is. Conceivably at such times the drift induced by the trade winds, and which is now diverted northward in the Atlantic to form the Gulf Stream, may have continued westward carrying with it some of the seed plants and animals of the islands situated where Central America now is.[17]

Likewise, any tropical cyclones that occurred then in the Caribbean region would have been more likely than now to sweep westward far into the Pacific, for the atmospheric pressure conditions prevailing over the land, especially mountainous land, seem often to divert tropical cyclones.

Likewise, it is known that Australia was formerly connected with Asia by way of the East Indies and New Caledonia. At such times, it is probable that the normal ocean currents were distinctly different from the present. While now part of the equatorial current finds its way westward between the islands and enters the Indian Ocean, formerly the continuous land necessarily diverted the warm equatorial current into higher latitudes.

Another change during the geologic past, which is much more frequently mentioned, is the lowering of the sea level during the accumulation of the continental glaciers of the several ice ages. It

[15] Best, Elston, "Polynesian navigators, their exploration and settlement of the Pacific." Geographical Review, vol. 5, pp. 169–182, 1918.

[16] For example, by Mayor, Alfred G., and Safford, W. E., in Proceedings First Pan-Pacific Scientific Conference, vol. 1, pp. 15, 147, 183–187, and by Best Elston, loc. cit. Safford has made especial study of the cultivated plants of Polynesia, loc. cit., pp. 183–187. See also Guppy, H. B., "Observations of a Naturalist in the Pacific," vol. 2, on "The distribution of plants and animals," London, 1908.

[17] Brown, F. B. H., loc. cit.

is thought by some that the sea level was lowered about 60 feet during the Pleistocene glacial epochs. Unquestionably there was some lowering of the sea level, but probably not nearly that much, for the glaciers probably were not nearly so thick as some have assumed.[18] However, any considerable lowering of the sea would result in an increase in the land area, sometimes connecting neighboring islands, and hence facilitating the local spread of land forms.

DURATION OF GEOLOGIC TIME

The recent great increases in the estimates of the duration of the geologic past also has a bearing upon the subject of tropical cyclones and the dispersal of life in the Pacific. It is conceded that the chances of a single hurricane doing much along this line are small. The great reason why hurricanes have been largely ignored by the students of this problem is because hurricanes were believed to occur only at long intervals and were thought to be too rare to play much of a part. But now that it is known that more than a score occur annually, on the average, out in the Pacific (in addition to those in the Philippine region) they take on a different aspect. Their significance is also increased by the fuller appreciation of the diverse ways in which they affect the lands, streams and currents. They are also less likely to be ignored as a factor in the dispersal of life when it is realized that the interval since the beginning of the Mesozoic era probably is many times the 20,000,000 to 50,000,000 years it was thought to be a few decades ago. Indeed, the remarkably convincing evidence, derived by leading physical chemists from the study of the products of the disintegration of radioactive substances in igneous rocks of various geologic ages, indicates that probably more than a billion years have elapsed since life became abundant upon the earth. Hence, fortuitous happenings, such as the dispersal of living forms by hurricanes, have had a long time in which to succeed.

[18] Huntington and Visher, "Climatic Changes, their Nature and Causes," New Haven, p. 125, 1922.

ISOLATION WITH SEGREGATION AS A FACTOR IN ORGANIC EVOLUTION

By David Starr Jordan

The purpose of the present paper is to stress the fact known to every field worker in zoology or botany, that the molding of species is mainly due to the separation by barriers of one kind or another of related forms. There is probably not a genus in which separate species have arisen in nature, that does not show that these forms have some sort of geographical basis. There is not a case on record in which the origin of a distinct species in nature can be traced with any probability to "mutation" or to Mendelian or other hybridism. That striking mutations occur in nature, as well as in the garden is well known. Selective breeding will carry these very far, but in open competition such variants are either crowded out or else swamped by interbreeding with the mass. No normal definition of species can be drawn from variants of this kind. A species is a recognizable kind of organism produced in the natural divergence of life, and which has run the gauntlet of time, and which has endured. The problem of the origin of species relates to forms which have lasted. The study of impermanent variants, whether due to mutation or to artificial selection and segregation is a matter of great importance. Among other things it should throw light on the origin of actual species, but the problems involved in the two cases are quite distinct.

To begin with, forms actually found in nature we must consider as genuine species. Nothing can be more real than that which really exists. Natural species, nevertheless, have as a rule indefinite boundaries shading off into subspecies, geminate or representative species, ontogenetic forms and the like, and may be variously altered by artificial selection in conjunction with artificial segregation. All their multifarious eccentricities command attention. As Darwin once observed, such facts are fascinating to us "as speculatists, however odious to us as systematists." They must be reckoned with, not through speculation but by intimate understanding of actual realities. But to extend our knowledge of a species we must ring the changes on the variations to which it is susceptible. For the degree of variability is also a specific character. On such problems hundreds of

geneticists are now at work, with the handicap that their studies look forward to changes that may be effected, not backward to ancient responses to shifting environment.

In the study of any species whatever, we encounter four factors: Two intrinsic—heredity and variation; two extrinsic—selection and isolation or separation, with its accompanying segregation, the one insuring the nonsurvival of the nonadaptable, the other leading to mating by propinquity, through biological friction which prevents wide crossing by interrupting the fluidity of life. Factors other than these four may exist, but in the history of every individual of which a species is composed, each of these has been potent. With that fact in mind, in view of the great range of investigation covering these matters, one may affirm that no wide-reaching biological problem is more completely explained than that of "the origin of species."

The historic origin of individual species of living organisms runs closely parallel with the origin of individual words in a language. One may trace the derivation of thousands of words, while yet hesitating or "expressing agnosticism" as to the origin of language. In like fashion, we may trace back to their original stocks thousands of animal or plant species and still hesitate about or "express agnosticism" as to a complete definition of biological origins. For after all each one has its own history, including vicissitudes of migration, selection, and separation; and the theoretical generalization can be only an inductive summing up of all evidence obtained.

In the study of species as related to geographical conditions, one is most impressed by the recognition of "twin" species, forms closely related but nevertheless distinct, separated from each other by some kind of barrier. To similar parallel forms I gave, in 1908, the name of "geminate species." These agree with each other in generic structural traits. In all matters of adaptation to environment, presumably results of selection, they may be absolutely identical, as also in habits unless confronted by some novel condition. They differ in minor regards, presumably of later origin than the generic traits.

I indicated the "law of geminate species" as follows: Given any species in any region, the nearest related species is not likely to be found in the same region, nor in a remote region, but in a neighboring district separated from the first by a barrier of some sort or at least by a belt of country the breadth of which gives the effect of a barrier.

The ornithologist, Dr. Joel A. Allen, accepted this generalization and called it "Jordan's Law," though of course it rests on the

observation of many workers. For it is a matter of common knowledge among field naturalists that the minor differences which separate species and subspecies are due to some form of isolation with segregation. Selection produces adaptation, but the *distinctive characters of species are*, in general, *nonadaptive*. By some barrier or other the members of one minor group are prevented from interbreeding with those of another minor group or with the mass of the species. As a result, local peculiarities are fixed. "Migration holds species true, localization lets them slip," or rather leaves them in the backwash of currents of evolution. Peculiarities thus set off by isolation become intensified by in-and-in breeding, or segregation, and the particular environment exercises some continuous type of selection until at last there emerges a new form, recognizable as distinct. And while its range rarely coincides with that of the parent species, or with any other closely cognate form, neither is it likely to be located far away. In the few cases where the range of geminate species overlaps in any degree, the fact seems to find an explanation in the surmounting (to some extent) of a barrier by one or other of the twin forms. The obvious immediate element in the formation and molding of species is therefore isolation, with (behind) the factors of heredity, variation, selection, and others as yet more or less hypothetical.

Illustrations of geminate species of birds, mammals, fishes, reptiles, snails, and insects are well known to all students of these groups; examples may be found on every hand. I have myself gathered the record of hundreds of pairs of zoological twins, an enumeration for which the present paper has no space.[1]

It is clear enough that species change with space and with time. With space, because separation takes place and new environment brings new stress of selection while isolation of individuals involves some difference in parentage. In like fashion, species change with time, because new conditions arise, new enemies, new foods, new separations, new selections. That notable differences obtain in time, even in pure strains, and when there is no visible reason for change, is clearly shown by the experience of stock breeders. In geologic time one geminate species often follows another and in the same locality, a fact lately shown by the writer in an extensive survey of the Miocene fish fauna of California.[2]

The application of Jordan's Law to plants has been denied. But geminate species are just as prevalent in botany as in zoology, and the effects of isolation in species forming among plants are

[1] See Dudley Memorial Volume, Stanford University Press, 1913.
[2] Fossil Fishes of the California Tertiary: Stanford University Press, 1921.

just as distinct. They are merely obscured by special conditions which obtain among plants.

Crossing the Temperate Zone anywhere on east and west lines, we find plant after plant replaced across barriers by closely related forms. Illustrations may be taken from among the higher types—equally well no doubt from among lower ones. Some genera belt the earth or come very near doing so, each form having its twin as next neighbor. A single example, that of the plane tree, *Platanus*, may suffice. Another would be the blackberry, *Rubus villosus*, and related species.

A natural law is not invalidated by the presence of effects due to other causes in the same environment. Actual conditions in nature are everywhere products not of single and simple forces, but resultants of many causative influences, often operative through the long course of ages.

As a rule, related species in almost every group are connected by a fringe of intergradations or subspecies. Where barriers are sharply defined, geminate species also are sharply defined. Where diffuse, geographical subspecies connect them, either wholly or in part. We recognize no difference between species and subspecies except that involved in sharpness of definition. If the particular barrier can not now be crossed, a species resultant from the presence of the barrier will be well defined and therefore unquestionable, however small the elements of difference. Subspecies are almost invariably associated with some feature of geographical distribution.

It has been claimed that geminate forms are not true species because they often intergrade one with another, and would probably be lost by intermingling were the barriers removed. Some maintain also that only physiological tests can be trusted, as true species will not blend and their hybrids, if they exist, are sterile. This assumption is purely hypothetical. Interbreeding is no test of species. Closely related species in almost any group of plants or animals can usually be readily crossed. As the relation becomes less intimate, we find partial sterility of varying grades and at last total incompatibility.

In most groups, probably in all, the characters which distinguish species from one another are elements neither useful nor injurious. Unless we take "natural selection" to cover both processes, as Darwin certainly did, we must assign to "selection" the preservation and intensification of adaptive characters, and to "isolation" the seizing and fixing of the nonuseful—usually fluctuating—element. It is a fact well known to breeders that these indifferent or nonuseful characters are generally more persistent in heredity

than traits which are plainly adaptive. The slight traits which mark races are in themselves not obviously valuable in the struggle for existence.

Moritz Wagner, the pioneer in this line of investigation, showed plainly that in the study of the evolution of any form we need to know where its has lived, what it did, how it was bounded, and what was its relation to other forms, geographically as well as morphologically. His work, a most necessary supplement to that of Darwin, has never received the attention it deserves. This is due in part to the fact that most investigators do not travel. They know little of animal or plant geography at first hand. They have had nothing to do with species as living, varying, reproducing, adapting, and spreading groups of organisms. Another reason lies in Wagner's attitude of opposition to Darwinism. For natural selection he substituted separation, "*räumliche Sonderung*," denying altogether the potency of the former factor. He saw the two as competing, not cooperating elements, and thus threw on isolation the impossible task of accounting for adaptation. One need not ascribe to natural selection the "*Allmacht*" which some Neo-Darwinians have claimed for it, yet on the other hand those who reject it as a factor in organic evolution give no rational explanation of the universality of adaptive organs and adaptive traits, no clue to the most universal characters of organisms in general.

Certain writers urge that neither selection nor isolation are factors in evolution, but rather elements in species forming, a process defined as something distinct from evolution. They say that these obstacles in the stream of life only help to split on-moving groups of organisms into different categories, while the impulse to forward movement is internal and the changes of evolution proper affect groups as a whole, and are not concerned with dividing them into species.

Such a view may be questioned on two grounds; it is untrue as to facts, or else merely a matter of words. We know nothing of evolution *in vacuo*, of change in life unrelated to environment. All forms of life are split up into species, with adaptation to external conditions visible in every structure. We know of no way in which organisms become adapted to special conditions except by the progressive failures of those which do not fit. No organism has escaped or can escape the grasp of selection. In like manner, the world being full of physical barriers, no organism escapes biological friction which prevents uniformity in breeding. There must be some degree of "*räumliche Sonderung*," even in a drop of water. As Wagner truthfully observes: "*Ohne Isolirung keine Arten.*"

To admit known facts and yet say that selection and isolation are not factors in evolution would appear to make the matter a mere question of words. If by evolution we mean the theoretical progress of life, due solely to forces intrinsic in organisms, then outside influences are of course not factors in such evolution. If, however, we mean the actual life movements of actual organisms on this actual earth, then extrinsic influences and obstacles are factors in continuous diverging change.

THE BIOLOGICAL ACTION OF LIGHT[1]

By Prof. Leonard Hill, F. R. S.
From the National Institute for Medical Research

While the heat spectrum, including infra-red, visible and ultra-violet rays, extends from a wave-length of some 60,000 $\mu\mu$[2] to one of 100 $\mu\mu$, beyond the outer dark heat rays are the Hertzian waves used in radio with wave lengths extending to a thousand meters or more. The inner dark heat rays merge into the visible, which are wave lengths from 700 $\mu\mu$ (red) to 400 $\mu\mu$ (violet). Beyond the visible lie the invisible ultra-violet rays with wave length from 400 $\mu\mu$ to 100 $\mu\mu$, and beyond these come the soft X-rays and then the hard X-rays and the γ rays of radium with wave lengths so short as 0.01 $\mu\mu$.

The body of a man is surrounded with a horny layer of skin beneath which lies the living cells of the epidermis in thin layers and myriad in number. Beneath them circulates the blood through close woven networks of capillaries, in streams some 0.01 mm. thick. The epidermis reflects and scatters rays which fall upon it, but some part of the visible rays penetrate and are absorbed by the blood beneath, warming it. The dark heat rays, on the other hand, absorbed mostly by the epidermis, warm it more than the blood in the dermis. Set as windows in an almost impenetrable skin, the eyes have been evolved with extreme sensitivity to a narrow portion of the spectrum—namely, the visible rays. To Hertzian waves we are insensitive; their energy has to be converted into sound and heard. Likewise we can not feel ultra-violet, X or γ rays; a latent period of two or three weeks follows exposure to X or γ rays before an erythema of the skin and irritation result. A latent period also follows exposure to ultra-violet rays, but one limited to hours. While the hard X-rays and γ-rays and secondary rays started by these penetrate in part to deep tissues, the active ultra-violet rays are wholly absorbed by the epidermis and exert their effect there.

Sonne found that if dark heat rays are brought to bear on the skin up to the just endurable sensation of burning, the temperature just beneath the skin will be raised to about 43° C. On the other

[1] Substance of two lectures given at the Royal Institution on Mar. 12 and 19; reprinted by permission from Nature, No. 2896, vol. 115, May 2, 1925.

[2] $\mu\mu$=0.000001 mm.

hand, if visible rays alone are concentrated on the skin to the just bearable degree, the temperature just beneath the skin will be raised even to 47° C. This result, confirmed by Argyll Campbell and L. Hill, is due to the greater absorption of dark heat by the surface layer of the skin and a deeper penetration of the visible rays. Sonne ascribes heliotherapy to the local heating effect of the visible rays and has tried to find evidence that such local heating of the blood increases specific antibodies of the body—e. g., the diphtheria antitoxic content of the serum. However, P. Hartley has reinvestigated this matter with great refinement and accuracy of method, both in regard to the diphtheria antitoxin content of the serum and the agglutinin content of the serum against *B. typhosus*, and finds that light baths have not the least effect on such a specific immunity. The baths have power, on the other hand, to increase the general resistance of the body to infection, as was shown by L. Colebrook, A. Eidinow, and L. Hill, who found that a light bath intense enough to produce erythema put up the hæmo-bactericidal power of the blood as tested in vitro. Blood which before the bath killed say 80 per cent of staphylococci mixed with it, two hours after a light bath killed 100 per cent. Such an effect followed no less when a lasting erythema was produced by exposure to heat or a mustard poultice.

In the case of the light bath the relative activity of visible and ultra-violet rays is proved in the following way: If an arc light with "white flame" carbon poles (direct current and about 2,500 kilowatts) is focussed sharply through a quartz lens on to the arm, an unendurable burning sensation results almost at once. If the arm is immersed in a quartz vessel full of cold water and the experiment is repeated, no burning sensation results, but if the exposure is continued for 5 minutes, erythema develops some hours later at the exposed spot, and this may advance even to a blister, to be followed by a long, lasting, brown pigmentation. Repeating the last experiment with a quartz screen filled with 3 per cent quinine solution interposed between the arc and the arm, all ultra-violet rays shorter than 330 $\mu\mu$ are thus cut out, as can be shown by the quartz spectrograph. In this case no erythema results even after over an hour's exposure. The visible rays then, apart from their heating effects, have no effect on the skin. The ultra-violet rays, acting on the cooled skin, have, on the other hand, a profound effect.

Using a quartz spectroscope and a blackened thermopile for measuring the energy of various parts of the ultra-violet spectrum, it was found by Hausser and Vahle that the maximal power for producing erythema of the skin was with the wave-lengths 300-290 $\mu\mu$, just the region which comes through with the high sun on clear days. Little effect was given by rays 313 $\mu\mu$ and 250 $\mu\mu$. A screen of uric acid

(1 in 40,000 solution) in a quartz container absorbs rays shorter than 306 $\mu\mu$ (Dhéré). The mercury-vapor lamp through this screen produces no erythema even after giving six times the erythema dose for the unscreened lamp. Lines 275 and 257 $\mu\mu$ of the cadmium spark spectrum produce erythema, but not line 232 $\mu\mu$. Such short rays do not penetrate the horny skin but actively kill infusoria.[3]

How slight is the penetrating power of the ultra-violet rays is shown by interposing in place of the quinine solution a thin film of the horny layer of the skin taken off a blister, or the mesentery of a rabbit. Such a film protects the skin no less that the solution of quinine.

The active ultra-violet rays penetrate to the deeper epidermic cells but no farther. Among these cells there takes place multiplication and growth, formation of pigment and transition into the horny material, which is pushed outwards by the growth of cells within In these cells the ultra-violet rays provoke changes which we may assume are similar to those which have been photographed in living anthrax bacilli by Mr. J. E. Barnard, using a microscope with quartz lenses and a band of ultra-violet rays from the cadmium spark. Under the ordinary microscope they have been observed by A. Eidinow and L. Hill on infusoria. An increasing aggregation of particles takes place in the bioplasm; in the case of infusoria this leads to cessation of movement, death, rupture, and setting free of the particles. So, too, the surface film of egg white exposed in a quartz chamber is coagulated by ultra-violet rays. Positive particles are dispersed and negative ones aggregated (Clark).

These rays displace electrons in atoms according to present physical theory and so alter the charge of the particles, some of which are to be seen in bioplasm by dark ground illumination and high microscopic magnification in active Brownian movement. This leads to aggregation started by the displacement of electrons in the atoms. Chemical change in molecular structure ensuing in the epidermal cells after a latent period, reaches such an irritative nature as to lead to dilatation of the subcutaneous blood vessels, exudation of lymph, increase of lymphocytes, and rise in the hæmobactericidal power of the blood. In cases of rickets the abnormally low inorganic phosphorus content of the blood which is significant of this condition is put up also in a striking way. Subsequent to these reactions there results desquamation, due to death of some epidermal cells followed by pigmentation. The pigment melanin is laid down as granules in that layer of living cells which lies close underneath the horny layer. Melanin is stated to be formed by the action of an oxydase in the deeper epidermic cells, as may be seen

[3] I am indebted to Messrs. J. E. Barnard and J. Smiles for the use of the spark.

in the fresh sections of skin (cut frozen) when radiated and wet with a solution of dioxyphenylalanin; this substance is said to be the specific precursor (Bloch). The closely allied compound, tyrosin, is said to diminish in amount in the blood at the time when melanin is being formed in the skin after a light bath.

Ultra-violet rays act more quickly on warm than on cold skin. Tested on infusoria the coefficient for temperature (for a rise from 10° C. to 20° C.) is about 2–3 (A. Eidinow and L. Hill); for the frog's mesentery it is less, about 1–2 (Argyll Campbell and L. Hill). While heat of the sun may aggravate a sunburn, it is not a necessary adjuvant. Ultra-violet radiation can intensely burn the cooled skin; it is well known that glacier sunburns may be very severe. Dewar killed microbes with ultra-violet rays at the temperature of liquid air.

The power behind the sun was worshipped by the heretic pharaoh, Akhnaton, and modern science leads us back to veneration of this power. The imagination tries to think of the infinitely intricate energy complex which goes to form a living cell, of electrons being displaced in atoms by ultro-violet rays, of molecular movement enhanced by heat rays, of radiation provoking reactions which manifest themselves as life, of the spirit of man ensuing in the evolution of energy transformations.

The law holds that absorption of rays precedes action. Rays which pass through a cell have no action upon it at all. The skin screens itself from excessive light by its horny layer and by pigment. Pigment by absorbing visible and ultra-violet rays screens the deeper cells and blood. It absorbs dark heat rays and converts visible rays into heat, and this heat, stimulating the nerve endings in the skin, may reflexly lessen body heat production while provoking sweating and dilatation of cutaneous blood vessels.

Melanin is a screen, not a sensitizer, transforming light into heat. It is present in a fine particulate form and scatters and diffusely reflects rays. The spectrograph shows that melanin in fine suspension and thin layers screens off and greatly weakens but does not wholly absorb the ultra-violet spectrum. This is in sharp contrast to a 3 per cent solution of quinine which in an equally thin layer wholly absorbs rays shorter than 330 $\mu\mu$. A layer of sweat wetting the skin helps to reflect light, while a layer of evaporating moisture surrounding the skin helps to absorb heat rays. The pigmented naked body with sweating skin is thus favorable to the cooling of the native in the tropics, while clothing retards heat loss of the white man.

By local concentration of an arc light on a rabbit's head, it is easy to heat its fur up to 150° F. and its brain even to 107° F., while with the body in the shade the rectum is only 101° F. (Argyll

Campbell and L. Hill). Pith helmets prevent local heating of the head and sunstroke in the tropics. In the West Indies, these are not needed owing to the screening of the sun by water vapor. There is rarely any danger of sunstroke in Great Britain. The sun is powerful enough only on few summer days, and bare heads offer no risks except on these rare occasions. Heatstroke from overheating of the whole body due to exhaustion of sweating in warm stagnant air is much more common—overclothed as we are for withstanding hot weather.

Downes and Blunt (1877) proved that the bactericidal action of light was due to ultra-violet rays, and much has been made of this. It has been claimed recently by Wiesner that the infra-red rays, apart from their heating effect, have a bactericidal action, but this is not so (A. Eidinow and L. Hill). The only rays which kill, apart from any lethal heating effect, are the ultra-violet rays. The bactericidal power of these rays is not nearly so important as has been thought, for the rays can only kill the surface bacteria. They can not penetrate into filth any more than through the epidermis. In their curative effect on lupus these rays act, not by directly killing the bacilli, but by increasing the immunizing powers of the tissues. This is so, even when the rays are focussed as in the local Finsen light treatment. Nodules so treated, when injected into guinea pigs, produce tuberculosis.

Mr. J. E. Barnard, by photographs taken with ultra-violet rays and a quartz-lensed microscope, has shown structures hitherto unrevealed in living yeasts, bacteria, and blood cells. This is due to the selective absorption by the outer membrane, the nucleus, and certain other granules in the cells. Infusoria vary in their susceptibility to the lethal effect of ultra-violet rays, and this probably bears a relation to the age, nutritional state, and absorptive particles within them. The lethal power on cells increases with shortening of the ultra-violet rays; for example, using the cadmium spark, a 20-minute exposure sufficed to kill infusoria placed in the 275 $\mu\mu$ band, and a 3-minute exposure in the 232 $\mu\mu$ band. The penetration of the shorter rays, however, is far less, and these therefore have no action on the skin. Thus, as stated above, while bands 275 and 257 $\mu\mu$ of the cadmium spark produce erythema of the skin, the intense 232 $\mu\mu$ band has no effect.

In the case of the very short rays, Mr. J. E. Barnard finds one anthrax bacillus screens another lying beneath it. With rays of weak intensity, processes of repair may keep pace with injury, and no effect be produced in living cells. A screen which allows ultra-violet rays to pass so as to give an excellent spectrum, as photographically recorded by means of the quartz spectrograph, may be

found to reduce biological action very greatly, as is shown when the lethal power of the screened rays is tested against that of the unscreened on infusoria or the skin. The photographic method is so exceedingly sensitive that deductions can not safely be drawn from it alone.

It is claimed that immunity is set up in the epidermis by one exposure to a subsequent one, and this long before pigment is formed (Perthes). Thus if an area of the skin be exposed for five minutes and again for five minutes some hours later, and a second area be given 10 minutes exposure all at one time, the erythema will be much more marked in the second area. Choosing a small dose, a second one given a few hours later increases erythema and soreness. Maximal erythema, of course, can not be further increased by a second dose, but this seems to be true for soreness also. The immunity is no doubt due to coagulation of the outer layer of living cells, whence comes peeling. When pigmentation is still well marked weeks after an exposure, susceptibility of the epidermis may be shown to have returned by the erythema following a further dose of ultra-violet rays.

To measure the therapeutic action of the ultra-violet rays we can use the lethal dose for infusoria contained in a quartz cell at 15–20° C., or the erythema-producing dose for the skin of the average white arm, or the rate of bleaching of a standard solution of acetone and methylene blue. The last has been standardized against the two former, and each degree on the scale is twice to four times that required to produce a moderate erythema. (A. Webster, L. Hill, and A. Eidinow.) The acetone blue solution is exposed in a quartz tube of standard diameter, and after exposure the degree of bleaching determined by comparison with a set of blue tubes of depths of tint 10 to 3. The acetone solution absorbs the ultra-violet rays shorter than 360 $\mu\mu$, and the chemical reaction set up in it bleaches the blue. Observations have been taken daily with full exposure to sun and sky at various places and show the intensity of ultra-violet radiation in clean air and the effect of smoke and pollution. During a fine summer day the quartz tube may have to be changed two or three times in the day, and the highest total reading last summer at Peppard, Oxon, equaled 23. In the Alps a reading of 41 was obtained in one day. In dull cloudy weather of winter the reading may be 1 or 2 and in smoke polluted towns 0.

Using in addition a clock to keep moving the quartz tube together with a small screen to shade it from the sun but not from the sky except that immediately round the sun, we have found that the total ultra-violet radiation from the sky is far more than from the

direct sun. Dorno at Davos showed that this was so using a cadmium photo-electric cell for recording the ultra-violet radiation. Even with the sun at its zenith, the ultra-violet radiation from it is only about 90 per cent of that from the blue sky. With the low sun, the sky yields far the more.

Smoke pollution robs us of half or more of the ultra-violet rays. While seeking to abolish this evil, we require to make the loss good by the use of artificial sunlight baths. Screened as he is by window glass, clothes, fog, and smoke, the citizen is cut off from ultra-violet rays almost wholly in winter, and in consequence his general health and resistance to disease goes down. The evil is enhanced by indoor life spent in heated stagnant air of rooms, and by lack of open air, exercise, and by a diet deficient in vitamins. Thus the resistance to catarrhal infections, which spread in the crowded stagnant air of rooms, is lowered. Those who live open-air lives and are well fed, exposed however much they are to weather, are far less often attacked.

It has already been stated that the hæmobactericidal power of the blood (as tested in vitro) is put up in an animal by an exposure to ultra-violet radiation which is sufficient to produce erythema. It has also been found by A. Eidinow that if a little blood is withdrawn from an animal, irradiated by rotation in a quartz flask, and then put back again into the animal, this puts up the hæmobactericidal power, and yet the irradiated blood itself has this power actually destroyed in itself by radiation. The putting up of the hæmobactericidal power depends on the corpuscles and not on the serum. In man it is naturally high, and can be put up less than in such animals as rabbits and pigs. It is known that ferments, serums, agglutinins, and the anaphylactic power of blood are alike destroyed by ultraviolet radiation in vitro.

Recent research on rickets has shown that the diseased calcification of the growing bones results from a diet deficient in antirachitic substance and lack of ultra-violet rays. If young rats are put on a diet deficient in antirachitic substance and having a minimum of salts of phosphorus, the latter is not absorbed from the gut. Either the addition of antirachitic substance in cod-liver oil or ultra-violet radiation for a few minutes a day will wholly stop rickets developing and cause a minimal amount of phosphorus in the diet to be absorbed and utilized in bone building (A. Webster). It has been proved that the antirachitic substance present in cod-liver oil is not vitamin A, and that it can be put into an inactive food by ultra-violet radiation (Hess, Steenbock). Thus, inactive linseed oil, casein, flour, and lettuce leaves can be made effective as cod-liver oil in preventing rickets, by rotating them in a quartz flask in front of

the mercury vapor lamp. Water, fat, starch, sugar, mineral oil, glycerine, can not be so activated. Oils retain their acquired antirachitic power for months. It has been claimed that "active" food substance on oxidation gives off ultra-violet rays, but this is not so. The error has arisen through the fluorescence of certain quartz screens used in the photographic tests (A. Webster). Drummond has shown that radiated cholesterol makes an extremely active radiated rats absorb this from the skin. The antirachitic vitamine activated by radiation this is the activated body. Probably too, radiated rats absorb this from the skin. The antirachitic vitamine or vitamine D is then sterol activated by radiation.

We have no evidence so far that radiation can endow an inactive food with the growth qualities pertaining to vitamin A. If this were possible, the margarine makers would have found a fresh source of fortune in being able to claim that their product was made equal to butter. Rickets can be prevented by making the diet more adequate—e. g., by cod-liver oil—and also by teaching mothers the need of exposing infants' and children's bodies to the sunlight and by the use of artificial sun baths at infant welfare centers.

Prolonged exposure to intense ultra-violet rays either of the sun or an arc light produces destruction and sloughing of the white skin. While the visible rays, beside their heating effect, have no lethal effect on the normal living animal cell, it is easy to produce a most powerful effect from these rays by sensitization of the cells. Many fluorescent dyes have this effect, eosin, erythrosin, etc., forming a compound with the bioplasm and so making the latter absorb and be affected by rays longer than the ultra-violet. The action of visible rays on sensitized cells depends on the presence of oxygen.

The most interesting sensitizer is hæmatoporphyrin, an iron-free derivative from hæmoglobin, closely allied to phyloporphyrin, a derivative of chlorophyll. Traces of porphyrin (uro or sterco) are present naturally in the body and may possibly give to the skin some very slight natural sensitivity to visible rays. An excess of porphyrin is present in some rare individuals endowing them with an unfortunate sensitivity which causes skin eruptions and even ulceration of extremities on exposure to bright light—a disease called hydroa æstivalis, which has to be met by the greatest care against their exposure to sunshine or bright daylight.

When the mesentery is exposed in a cool glass irrigation chamber to concentrated visible rays of an arc, no effect results, the ultra-violet rays being filtered off by the glass. Add now a trace of hæmatoporphyrin to the bath (1 in 10,000) and in a very few minutes stasis occurs in the blood vessels. The lymphocytes gather

to form thrombi which block the vessels (Argyll Campbell and L. Hill). While pigmented animals are protected, albinos made sensitive by injection of hæmatoporphyrin die after exposure to light. Meyer Betz was daring enough to inject some hæmatoporphyrin into himself and suffered from œdema of the face and hands on exposure to light. He remained sensitive for weeks. It seems possible that sensitization may prove useful in light therapy, but great caution in dosage is required. Painting patches of lupus with glycerin and eosin has been tried so as to endeavor to secure a greater local effect from light treatment, but definite evidence for this has not been found (A. Eidinow and L. Hill).

Sudden exposure to ultra-violet rays stimulates to contraction such an organ as the uterus of the guinea pig or the stomach of a frog. The excised iris by pigment is made sensitive and contracts on exposure to visible rays. Harmful ultra-violet rays do not pass through the cornea and lens, and when the retina is damaged by overexposure to an arc light or to sun (as in viewing an eclipse without smoked glasses) it is injured by excess of visible rays acting on its extremely sensitive substance. The lens may be damaged by overheating through rays entering the eye through a large solid angle and concentrated therein. Photo-electric effect produced by rays acting on a specific retinal substance or substances may be the first stage in the excitation of vision. Russ has claimed that the owl's eye transmits ultra-violet rays. As far as concerns rays shorter than 300 $\mu\mu$, this is not the case with the cat's eye, which has good nocturnal vision, nor with the cod's eye, a fish which swims in dim lights of somewhat deep water. Tested by putting the cornea in a band of biologically active ultra-violet rays, using the cadmium spark, none reach a fluorescent screen placed at a window cut in the posterior part of the eye (A. Eidinow and L. Hill).

It has been suggested that there is a biological interference between infra-red, or visible rays, and ultra-violet rays. Hess found a longer daily exposure to the mercury-vapor lamp necessary in order to prevent rickets in young rats (fed on a deficient diet) when a glass screen was interposed which let red and yellow rays through as well as ultra-violet, than was the case with a glass screen which only let ultra-violet rays through. The photographs of the spectra of the two screens seemed to show equality of the ultra-violet radiation, but a difference in intensity is the most probable explanation. Pech claims that both bleaching of cotton and production of erythema by ultra-violet rays is delayed by a concomitant beam of infra-red rays. Infusoria seemed to move actively longer in the light of a mercury-vapor lamp when red

rays were also thrown on them than without these rays. The lethal times, however, on further trial came out to be the same in the two cases, and further research on the circulation in the mesentery and on infusoria exposed to ultra-violet bands in the cadmium spark spectrum proved negative. Not the least evidence of interference with the lethal effect was found. (A. Eidinow and L. Hill; Argyll Campbell and L. Hill). So, too, in the case of excitation of involuntary muscle (Azuma and L. Hill).

Ultra-violet rays improve the growth and breeding power of fowls. Acting directly on embryos they produce monsters. The loss of breeding power in man and domestic animals such as cattle is probably due largely to indoor life. It has been established by abundant clinical experience that light treatment is excellent for surgical tuberculosis, rickets, and wounds (O. Bernhard, Rollier, Gauvain, and others). Trials recently made on many other diseases have shown that we have in artificial sun treatment a powerful stimulant to general health and in particular of the defensive mechanism of the body against chronic infections. Skin diseases such as psoriasis, ichthyosis, eczema, and boils, chronic anæmias of obscure origin, nutritional weakness and wasting in infants, chronic bronchitis and the fat flabby condition of the sedentary over-fed middle-aged person, chronic phthisis, the debility following actute infectious disease, etc., are alike greatly benefited (A. Eidinow and L. Hill; P. Hall, etc.). The open-air sanatorium and school have shown how ailing feeble children can be turned into happy vigorous ones.

A very great benefit to general health can at once be secured by the installation of arc baths in schools and public baths. If in winter all children stripped but for a loin cloth, danced to music for 15 minutes twice a week a yard or two away from and round a powerful arc lamp—e. g., one taking 100 volts and 30 amperes with white flame carbons—a great improvement in vigor, alertness, and health would be obtained. It is by such means that our misty, smoky, winter climate can be immediately remedied. At the same time, we can set about to secure and use smokeless fuel and clean away the hideous smoke pollution of the air. We can also set into windows and sky-lights of schools, hospitals, and nurseries the new "vitaglass," which lets the ultra-violet rays through, and use such glass for the bulbs of incandescent tungsten filament lamps, which would then be a source of ultra-violet rays of mild intensity.

Many interesting experiments are now being carried out concerning the growth of plants and fruits with and without ultra-violet rays, and on the effect of continuous lighting.

ANIMAL LIFE AT HIGH ALTITUDES[1]

By Maj. R. W. G. Hingston, I. M. S.
Naturalist to the Mount Everest Expedition of 1924

[With 2 plates]

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This paper is a condensed account of certain observations in natural history made while serving with the Mount Everest Expedition. It refers to life on the Tibetan plateau, especially with regard to the struggle for existence in those bare inhospitable tracts above the limit of the Himalayan tree line.

First, a word as to physical features. Tibet is a desert, a high-altitude mountainous desert at an elevation of about 14,000 feet. This is a point we must thoroughly realize, for the life of Tibet is in many particulars the life of a desert waste. Compare it for a moment with a low-lying wilderness, such as the sweeps of open sand in Arabia, Sahara, or Sind. It differs from these in one particular: It has none of their intense heat. But otherwise Tibet is essentially a desert—empty, bleak, and bare. As we travel across it we see all the features of the desert, the wide tracts of brown and barren soil, the vast distances spread out before the eye, the fierce display of light. Here, as in the desert, we meet tracts of sand, often loose and crumbling and at the mercy of the wind. In one place we see how its surface is rippled, in another how it is covered with a saline incrustation, in another how it stupifies the scanty vegetation or piles itself into crescent dunes. Here, too, we observe the same cloudless skies, the same glare from the plateau soil, how the air rises in shimmering waves or clothes the surface in a true mirage. There is the great range of temperature characteristic of the desert, often 50 degrees between day and night. The rainfall is scanty. The atmosphere is so dry that it splits the skin and nails, and prevents the ordinary decomposition of flesh. Fierce winds blow across it from the main range, and these might be compared with the Sirocco or Shamal. Frequently they raise up vortices of dust which career over the empty plain. As in the desert, we ob-

[1] Reprinted by permission from The Geographical Journal, Vol. LXV, No. 3, March, 1925.

serve the same scantiness of vegetation, the monotonous growth that gives no color to the landscape, the absence of trees, the thorniness of the plants, the short active season in which flowers rapidly bloom and as rapidly die away. These are some of the desert features which we meet with in our journey through Tibet.

Let us consider the life of this high-altitude desert. How do the creatures live? How do they protect themselves? By what means are they adapted to the conditions of the heights?

Anyone who has traveled in a low-lying desert knows how important is protective coloration in the general scheme of things. It is exactly the same in Tibet. Examples are apparent on every side. Most of the common animals of the plateau are inconspicuous against the soil. But we must remember that the plateau is littered with stones, and not like many low-lying deserts, an even layer of sand. This gives an additional advantage to the animals. For not only do their colors blend with the surface, but their shapes and outlines are often lost to view, being confused with the scattered stones.

I will give some examples of protective color in Tibet. Everywhere on the plateau we meet with colonies of pikas, delightful little creatures which sit near their burrows and blend with the sandy soil. In the gorges of the main range we find another species. Its surroundings are more gloomy; it lives amongst rocks, and in accordance with this its coat is darker so as to fit it to these special haunts. The marmots likewise blend well with the altitudes. They like to occupy the bare passes as high as 17,000 feet. The Tibetan hare is a good example of harmonization, especially when it sits amongst fallen stones. Some of the larger animals are protectively colored. The Tibetan gazelle is the color of the plateau, and a herd of burhel is inconspicuous against a hill.

The majority of the birds are protectively colored. The different kinds of mountain finches, the Tibetan skylark, the short-toed lark, the calandra lark, the Mongolian sandplover, are all colored so as to harmonize with the soil. They all live on the open plateau where there is nothing to conceal them from view. Two of the birds have conspicuous markings, but these do not interfere with the concealing effect. The desert chat, for example, has white patches on its wings which disappear from view when the bird alights. The horned lark has black markings on its neck and breast, but these are sufficiently well concealed from a hawk or other enemy soaring overhead. The Tibetan sand grouse is an excellent example of harmonization; so is the magnificent Tibetan snow cock when feeding amongst the bowlders and crags. The cliffs and torrents also provide examples. The wall creeper lives around the fort at Shekar, and as it climbs about the slaty rocks the color of its back blends with the stone. The

ibis bill is a more striking instance. As it feeds amongst the bowlders in the bed of the torrent it is lost to view in the midst of the stones.

Some of the birds are not thus protected. But in such cases they are able to defend themselves from enemies or have special places into which they can escape. The raven, the steppe eagle, the kite, for example, are so powerful that they need no protection. Certain little birds, like the sparrows and accentors, are conspicuous, but they keep near villages or piles of stone amongst which they can escape from birds of prey.

We see numerous examples amongst other creatures. The lizards on the plateau are very variable in coloration. Some are uniformly sandy, others coarsely speckled, but all harmonize with the arid soil. There are different kinds of grasshoppers that haunt special situations. One, a large central Asian migratory species, is rich green in color and lives in patches of fresh grass. Another, a new genus, minute and wingless, lives on the moraines and decomposing granite as high as 18,000 feet. It is finely mottled in grey and black, and difficult to see because it closely resembles one of the granite flakes. There is a third kind which keeps to tracts of coarse loose sand. In its color scheme are patches of blue and red, and these harmonize with similar colors in the grit. Still another kind haunts the water-worn pebbles on the banks of the Chiblung Chu. This little grasshopper is a uniform blue color, and exactly the same shade as the layer of stones.

It would be tedious to mention all the other examples. But I must refer to the high-altitude moths which frequent the moraines at 17,000 feet. These resemble a species of tiny *Anarta*. Their under surface is very conspicuous, but is concealed when the insect alights on the rock. Their upper surface, on the other hand, is a mottled grey, which blends with the granite and the decomposing grit.

Thus we see how important is protective coloration in the struggle for existence at these great heights. It is in the vast and open tracts, the deserts, the snows, the elevated wastes, that we have this principle most lavishly displayed. The reason for protection of this kind is clear. In the wilderness hiding places are seldom available. There are no trees, no scrub, no profusion of grass in which the animals can conceal themselves when enemies approach. To avoid destruction they must seek evasion of some sort. Their only chance is to resemble their natural surroundings and escape by being passed unseen.

I pass to another problem. How do the animals of these high altitudes adapt themselves to the physical conditions that exist? Consider first their reaction to the wind. Tibet is notorious for its fierce winds. The morning sun heats the surface of the plateau, the

hot air rises, and in order to fill the deficiency the wind sweeps down from the main range. Near our base camp we saw an excellent example of its force. The camp stood in a contracted gorge through which the wind poured down from the mountain to the plain. Round about the camp were piles of boulders which the Rongbuk glacier had deposited in the gorge. These bowlders were remarkably eroded by the wind. Deep pits and furrows had been eaten into them; they were polished, and broad grooves had been cut into their surface, in places an inch in depth. They were composed of granite and recently deposited, yet from their windward side they looked like lumps of coral while their sheltered surface was ordinarily smooth.

Let us see how the animals react to a wind which can eat into the granite rock. The mammals are often clothed in thicker coats of hair. We see this in the herds of domesticated goats, delightful little animals with long hair that hangs down like a kilt around their legs. The Tibetan dogs are often thickly clothed. Sometimes we may see them in the early summer shedding large patches of winter wool. Near Gautsa I saw pigs at 12,000 feet, and they were covered in a thick rusty-colored hair quite different from the half-naked animals of the plains. The Tibetan hare has a dense coat, and it ascends to 17,000 feet. But the ordinary yak is the best example. Next its body is a layer of wool. Over this is a hairy coat which hangs down like an apron from its huge body, especially around its legs. Its neck is provided with a strong mane, and behind it supports a large tail of thick and bushy hair. When the yak is grazing we see the value of this coat. The animals like to feed with their backs to the wind. The thick tail then acts as a kind of wind-proof screen; the long hair around the hind legs adds to the shield, while the head, being kept low, is sheltered by the body and protected above by the hairy mane.

Everywhere we see the birds adapting themselves to the wind. The little birds escape it by getting behind obstacles. Thus we often see the larks, the finches, the ground choughs feeding on the sheltered side of villages and walls. When in the open they persistently face the wind; if they stand across it they may literally be lifted off their feet. The larger birds follow a similar habit. The choughs face the wind when feeding on the pastures; the ravens do likewise when scavenging for refuse; the lammergeyer always heads it when descending for bones; the kites persistently come round to windward before swooping down to take garbage from the ground. Those birds that live around rocks and habitations creep into some shelter when the wind blows. We see the sparrows hiding in the holes of the houses, choughs getting into the lee of rocks, rose finches nestling

under ledges and stones. A great number of the birds make their nests in holes, and in this way shelter their offspring from the wind. The mountain finches and the ground choughs place their nests in pika burrows, often at a great depth. The magpie builds an enormous nest. I think it serves the parent birds as a permanent shelter in addition to serving as a home for the young. The birds that build on the ground place their nests behind tufts. The short-toed lark showed in one case an interesting modification; it built a rampart of pebbles on the exposed side of its nest so as to protect the structure by an artificial wall.

Certain of the butterflies show interesting adaptations. The Parnassius or Apollo butterflies are characteristic of high altitudes. In Tibet they haunt the passes up to 17,000 feet where the wind sweeps furiously across the range. They are capable of only feeble flight, and are easily carried along by a gale. They escape being swept away by their unwillingness to fly, except when the air is comparatively still. Moreover, when disturbed, they made but short flights; also when they alight they choose sheltered nooks, and their resting attitude is to spread their wings, pressing them down close against the ground so as to offer the least resistance to the air. Furthermore, their wings are stiff and rigid and not likely to be torn when being battered about. Also their bodies are clothed in fur, which must serve as a protection against both cold and wind.

The Swallowtails and Vanesidæ also haunt the plateau. They used to come about our base camp at 17,000 feet. But these butterflies are particularly powerful fliers, and by their strength alone can contend with the wind. Other kinds live at slightly lower altitudes. There is a *Melitea* on the plateau which has the habits of the Apollos. It escapes the wind in the same way by flattening itself tight against the ground. The Lycænids like to keep in sheltered places. One kind gets into the tufts of vetches, another conceals itself in coarse grass. The high-altitude moths that resemble *Anarta* adapt their habits to the fierce winds. They haunt the tracts of fallen rocks, the bare hills, and deposits of moraine. They fly about by day, alighting on the sand. When the wind is strong they enter clefts in the rocks or else shelter between the stones. Their flight is swift and of short duration. When they alight they behave like the Apollo butterflies, flattening themselves with outstretched wings against the rock, thus offering the smallest obstruction to the wind.

The Diptera that haunt the cliffs at 16,000 feet like to keep close in amongst the stones and rocks. Moreover, they make only short quick flights. Their actions are more like the leaps of a grasshopper than the ordinary movements of a fly. There is one kind, a *Tachinid*.

which haunts bowlders at the edge of the rivers. It has a black hairy body, a spined abdomen, and grayish speckled wings. Now this fly seems almost incapable of flight, so reluctant is it to take to the air in a wind. Its habit is to seek for shelter beneath bowlders, and, when these are upturned, it can be taken in the fingers, allowing itself to be captured rather than escaping by flight. There is another kind of the genus *Gonia* which likes thorny bushes. It comes out on sunny mornings when the air is calm. But its flights are short, only a few feet, as if it feared to trust itself to any distance in the air. Moreover, it strives to keep within the shelter of the scrub, flitting about from twig to twig or coming to rest on the sand beneath. Thus it manages to evade the wind, partly by reason of its short flights and partly by keeping within the scrub.

Some of the digger wasps avoid the wind in the same way. They have learned to keep close in amongst the bowlders, also make only quick short flights in order to avoid being swept away. Many of the insects on the plateau are wingless. Numbers find continual shelter under stones. Grasshoppers ascend to 18,000 feet. But at this altitude they are minute and wingless and escape the wind by their inability to fly. The *Pseudabris* beetles provide an interesting example. These beetles are conspicuous and brilliantly colored with alternate bands of black and red. They usually hang in clusters on the vetches, where they feed on the young shoots and flowers. Watch them when a strong wind suddenly springs up. They let go their hold and throw themselves to the ground. There they lie, all apparently dead. Each is on its side; its head is bent at right angles to its body; its antennæ are turned downwards; its legs are collected into a cluster and thrust out like lifeless tags. They all lie in the attitude of death like a crowd of corpses strewn over the ground. When the wind lessens they quickly revive, they run over the soil, regain the vegetation, and climb back to their places on the vetch.

Thus we observe that the animals of high altitudes contend with the wind in many different ways. Some grow denser coats, others seek sheltered places, and there is a great tendency to burrow in the soil. Certain butterflies and moths flatten themselves on the ground; many insects make only quick short flights; certain flies keep in amongst stones and bushes; high-altitude grasshoppers and other kinds are wingless; certain beetles throw themselves for safety to the ground.

Let us pass to another phase in the struggle. How do the animals at high altitudes contend with the scarcity of food? The domestic animals show us how severe is the struggle. It is wonderful to see a herd of yaks grazing on the hillsides. To all appearances the moun-

tain is absolutely barren, yet the animals manage to pick up some food. When snow is on the ground they dig through it to the vegetation. The Tibetans said that they scraped up roots. I have seen them eating the fresh dung of a pony which had been well fed on grass and grain. In April, when the grass is just commencing to appear, the sheep struggle hard to obtain food. With their fore feet they dig into the soil and shuffle aside the superficial sand in order to get at the buried blades. When food is scarce, the ponies do likewise. I have seen them cutting up the ground with their hoofs in order to expose the hidden roots. Also they wade into icy lakes, where they feed on the water weed that grows up from beneath. The mules and donkeys will sometimes eat quantities of yak dung, which does not seem to do them any special harm. The pikas show an excellent example of husbandry. They store up quantities of seeds in their burrows to serve as a winter supply of food.

The bills of certain birds seem specially suited for penetrating frozen soil. This is of importance for the insectivorous species, since in winter, when the ground is hard, all insects are hibernating underneath stones or in the superficial layer of the earth. Compare the bill of the chough, an inhabitant of high altitudes, with that of its allies, the rook and crow. The chough's bill is proportionately longer and sharper and better fitted to penetrate the frozen soil. It is also used as a kind of lever with which the bird upturns the lumps of dung in order to reach the good things underneath. The ground chough is a delightful Tibetan bird of a sandy color that harmonizes with the soil. It is about the size of a lark, but is supplied with a long and powerful bill, slightly curved like that of a chough. Now this bill fulfils an important purpose. The bird is an insect feeder, and must find great difficulty in securing food during the cold months of the year. All insects are then in a state of hibernation. But the ground chough can dig them from their places of retirement. We may often see the bird boring in the soil, driving its stout bill into the hard plateau until it finds the insects hidden underneath. Unless it had this special instrument of excavation it could scarcely exist through the winter months.

The larks supply another example. In India there are two kinds of Calandra larks: One the Eastern Calandra lark, which lives on the plains; the other the long-billed Calandra lark, which occupies the plateau of Tibet. They are powerful birds of heavy build, and utter a loud call note when in flight. Compare the bills of these two species. That of the plain bird is comparatively small, about four-fifths inch in length. That of the Tibetan bird is distinctly longer, its length being 1⅕ inches. The longer bill of the Tibetan

bird is explained by its environment. It ploughs into the ground after the manner of the ground chough, hammering the surface with its powerful bill and securing its food by boring into the soil. And since the soil is often frozen and difficult to penetrate, this species of the plateau must have a sharper bill than the closely allied species of the plains.

That remarkable bird, the ibis bill, provides an excellent example of how the bill of a bird is adapted to its method of securing food. It is a high-altitude wader with a long hard and slender bill curved something like that of a curlew. This bird is met with in the mountain torrents that pour from Tibet into the Himalayan range. It specially likes those places where the stream is broad and meanders through a bed of stones. There it runs about upon the layer of boulders, sometimes wading into the torrent up to its breast, thrusting its long bill under the stones in the hope of finding insects beneath. Sometimes it curves its bill around the front of the stone, sometimes inserts it from one side. The bill is an excellent instrument for this purpose. Were it straight, it would not suit the roundness of the pebbles. The curve is a necessary feature of the implement, and is excellently adapted to the habits of the bird, for it is curved in such a way that it fits neatly around the boulders when the bird is probing for food.

The peculiar environment of the Tibetan plateau has caused some of the high-altitude birds to change their customary habits of life. Some kinds, owing to the absence of trees, have become almost exclusively village birds. Thus the tree sparrow is to be found near every habitation. The accentors, which usually haunt bushes, in Tibet live amongst houses and in streets; also the rose finches, which naturally like jungle, are frequently seen on the village walls. The magpies are like house crows in the way they keep to the villages, and, like choughs, they frequent precipitous cliffs. Many of the wildest birds have lost their sense of fear. The ruddy sheldrake and the bar-headed goose, which in India are amongst the most timid of birds, in Tibet swim about the ponds near the villages as fearlessly as in a city park. The hill pigeons fed as boldly at our Everest base camp as if they were the tame birds in a London street. We observe the same tameness in the case of some of the mammals. Wild sheep, for example, are naturally very timid, yet at the base camp they came within 20 yards of our tents, and they are said to visit the caves in the mountains, where they take food from the hermits' hands. Thus we see how pliable is animal instinct. This usual tameness must be due to the absence of persecution, and shows that the sense of fear is not altogether innate, but is developed as a result of persecution by man.

Certain birds of the plateau have formed communities with other animals, this being a help to them in securing food. The most interesting of these is the mouse hare community. The mouse hares are most engaging little animals about the size of a large rat. They live in burrows on the open plateau, where they are usually seen feeding at the entrance or running from hole to hole. A number of birds associate with these mouse hares. Amongst them were three kinds of mountain finches and Elwes' horned lark. All these little birds were remarkably tame; there was a perfect confidence between them and the mouse hares, the whole making a charming society of protectively colored mammals and birds. What is the object of this friendly association? It is one of the ways in which the birds of the plateau contend with the scarcity of food. For these birds are seed-eating species, and find special attraction near the mouse hares' holes. The mouse hares possess an instinctive forethought. They store up a winter supply of seeds, which they carry into their dens. But where storage takes place there must certainly be some refuse. Little seeds will lie about in the vicinity of the burrows, and it is these waste fragments that attract the birds. Very possibly the birds also pillage the mouse hares, for we often observed them entering the holes.

At greater heights, on the almost barren mountains, a less conspicuous society may occasionally be seen. This is an association of choughs and wild sheep. The chough sits on the wild sheep's back, where it searches for insects in the animal's hair. The sheep seems pleased with the bird's attention, and remains still while being explored. It is an interesting association at the highest altitudes. I have seen it on the crumbling snow-clad slopes as high as 17,000 feet. Thus the stress of food at these elevations drives certain birds to associate with mouse hares; others to keep company with wild sheep. The wild sheep at high altitudes are continually displacing small rocks and stones. At different times my notice was first attracted to the animals by the clatter of stones falling down the slope. It is thus likely that these animals play no small part in the denudation of high-altitude cliffs.

I pass to another point. How do the animals escape the cold of winter? A number, of course, migrate to lower altitudes; but of those which remain, most go into hibernation and sleep the winter through. When we reached the plateau, early in April, we found it almost destitute of animal life. Everything was hibernating underneath stones or in clefts of the rock or in the surface earth. The ants were hidden in subterranean galleries. Under stones were weevils quite motionless, also carabid beetles so torpid that they

were scarcely able to move. We found centipedes rolled into motionless coils, spiders lying dormant in the interior of snail shells, earwigs in a sluggish state with their antennæ thrust back along their sides. Under some stones were numbers of dead insects, as though many had sought concealment in the autumn and died during the winter cold.

Hibernation must be a valuable protection to the animals. At the base camp I made an artificial burrow like that in which the pikas are accustomed to hibernate. At a foot beneath the surface its temperature was almost uniform. From 8 a. m. to 9 p. m. it remained at 33° F., while during the same period the temperature of the air varied through 19° F. Thus by burrowing the animals gain great advantage. They escape extremes of temperature and find uniform conditions. In winter they gain it even still more when they hibernate in the soil under thick snow. The conditions under a stone are also favorable for hibernation, though not to the same extent as a burrow in the soil. At an altitude of 17,000 feet the temperature beneath a stone varied through only 12° F. during the 24 hours. In the same period the temperature of the air varied through 44° F. Thus the beetles, the spiders, and many other creatures gain more equable conditions by hibernating under stones.

The hot springs of Tibet supply a place of refuge in which animals can escape the cold. In one place we found these springs bubbling through the soil and flowing away in warm streams. The temperature of the water was 60° F. A varied life inhabited these springs, chiefly crustacea and different kinds of shells. The only snake from the Tibetan plateau that I know inhabits the hot springs. In my original report on the fauna of the plateau mention was made of small leeches found at a height of 16,000 feet. It was found, however, on more careful examination, that these little animals were in reality planarians.

In the struggle for existence at these great altitudes many animals are driven to extreme heights. It indicates how relentless is the force of nature to spread into every habitable corner of the earth. The wild sheep and mountain hares struggle up the ranges even to the barren slopes at 17,000 feet. There is a little redstart which places its nest at the same inhospitable height. We found grasshoppers at 18,000 feet, near the farthest limit of vegetable growth. We frequently saw the magnificent lammergeyer soaring round the mountain at 20,000 feet. We found bees, moths, and butterflies at 21,000 feet, spiders at 22,000 feet, choughs at the immense height of 27,000 feet. We found traces of a permanent animal existence far above the Himalayan snow line and 4,000 feet above the last vegetable growth. These were small spiders, and are the highest exist-

ing animals on the earth. They live in islands of broken rock surrounded by snow and ice. There is no sign of vegetation or living creature near them, and for food they eat one another.

Nothing illustrates better this high-altitude struggle than the manner in which animals secure a livelihood on tracts of snow and ice. We found an interesting fauna on the Rongbuk glacier at an altitude of 17,000 feet. The surface of this glacier was deeply fissured and to a large extent covered with broken rock. It seemed at first sight utterly barren, yet some grass grew amongst the rocky fragments, and patches of lichen appeared on the stones. Certain animals found existence in this desolation. I have seen a herd of wild sheep sitting on the glacier surrounded by pinnacles of ice and stones. Certain birds used to frequent the icy tract. The snowcock came down to it from the sides of the gorges, perhaps to find a little food on the surface moraine. I saw Guldenstadt's redstart high up on the glacier where nothing existed but débris and ice. A little stint, while migrating through the gorge, halted for a rest near a glacier pool. A tortoise-shell butterfly was sometimes seen on the glacier at 17,000 feet. A number of protectively colored moths used to live on its surface moraine. Beetles and small spiders found a shelter on it. It was the home of some minute flies. Even in the deep blue pools on the surface of the ice some creatures managed to secure a place. These pools were so cold that after sweeping them with a net the gauze remained frozen into a rigid bag. Yet in these pools were the larvæ of both stone flies and may flies, and other equally delicate kinds skated on the surface of the water.

We may sum up with the impression that the struggle is fierce in the high altitudes of the Mount Everest region. We have seen that numbers escape death through protective coloration; that many kinds have devices for escaping the strong winds; that at certain seasons the struggle for food is intense; that some birds are specially equipped to dig into the soil; that other birds are forced to change their habits of life, and some to form communities with mammals; that burrowing and hibernation are the great resorts by which animals escape the extreme cold; and finally that the ceaseless and relentless competition has driven animals to extreme altitudes, where they live above the snow line and on the surface of the glaciers in one of the most inhospitable regions of the earth.

1. YOUNG OF TIBETAN SNOWCOCK

2. BURHEL ON CLIFFS NEAR BASE CAMP

3. A YAK

1. ATTID SPIDER FOUND AT 22,000 FEET

2. YELLOW-BILLED CHOUGH IN BASE CAMP

3. BLUE HILL PIGEONS IN BASE CAMP

THE NEST OF THE INDIAN TAILOR BIRD

By Casey A. Wood

[With 5 plates]

Very few people have actually found a nest of *Orthotomus s. sutorius* (also known as *Sutorius s. sutoria*)—the Indian tailor bird. After reading one of the numerous descriptions of this wonderful structure published any time during the past century, the impression is gained that its discovery is an everyday occurrence. Investigation, however, reveals the fact that those who have lived for a long time in a compound where these pretty little wren-like birds are seen every day and in whose gardens they are known to breed, have never discovered a nest or even the tree where it was built. A number of amateur ornithologists who have studied the habits of these birds have told me that they failed to find the nests in spite of a careful search for them. To emphasize this peculiarity the birds seemed quite tame and raised one or more yearly broods under their very eyes.

The well-known writer on natural history, Capt. W. W. A. Phillips, to whom I am indebted for one of the nests figured in this paper, writes me, "This is the first tailor bird's nest I have found during a residence of nine years in Ceylon. The species is common enough but is such an adept at concealing its nest that it is very difficult to find it. The sample I sent you was discovered only because I observed the birds frequently in the vicinity of the bush."

The main reason that the nest is difficult to find is that it is built in the midst of thick foliage which is very little disturbed by the operation of nest building. In consequence it is almost impossible to separate, visually, the components of the nest from the surrounding leaves. Moreover—and this is important—the leaves used by the bird are always apposed so that only their upper surfaces are exposed. There is no contrasting of upper and under surfaces to attract the eye. Nor is there generally any alteration in the direction of the leaves; if they have a natural downward disposition, the nest is also pendent. If the foliage stands out horizontally the nest shows the same direction. To complete this camouflage, perforation of the leaf by the bird's beak rarely kills it, so that there is little or no dead foliage to indicate the probable whereabouts of the nest. A

final reason why more nests are not discovered is that they probably do not hold together more than a few weeks after desertion by the birds. The leaves composing the nests die and shrivel up or may fall off. Soon the neglected cornucopia-like structure disintegrates under the influence of wind and weather; it does not remain and become visible for a year or so—as many nests do—for the benefit of the collector.

The impression that the nest of the tailor bird is more common than it really is arises in part from mistaking other structures for it. For example, the ashy wren warbler, *Prinia s. socialis*, occasionally builds a nest that looks like that of the tailor bird; and there are other birds' nests that externally resemble it. However, the structure that commonly passes for the nest of *Orthotomus* is a small-sized house of the red ant, which is made of leaves whose edges are brought together and held in place by means of glutinous silk secreted by the ant itself. Many a time have I been shown an alleged nest of the tailor bird which was really built by this remarkable insect.

I congratulate myself, accordingly, on having seen a recently constructed nest built in a tree where I could study it at my leisure. I was spending a few days at Sigiriya, in the jungle of northeastern Ceylon, studying the remarkable flora and fauna of that district. The rest house where I lived had several plants flanking the front entrance, one of them a year old Sapu (*Michelia champaca*) seedling about 7 feet high, planted in that ever-useful container—a kerosene tin. These fast-growing sapus always make effective ornamental shrubs, with their large lanceolate leaves and sweet-scented, creamy-white flowers. Although people constantly passed within a few feet of the *Michelia*, not until the small birds were noticed flying in and out of the foliage was it suspected that they were nest building. One day the rest-house keeper noticed that one leaf of the small sapu was marked with white dots and, while examining it more closely, he saw a tailor bird fly from behind it. Having marked the exact spot he was able to locate the nest and to watch the processes of raising the family of two small tailors. It was quite shortly after the birds had left the nest that I saw it.

Orthotomus sutorius, which we may translate "the straight-cutting tailor," loves to dwell in gardens and in the vicinity of human habitations, but it is also found in the grass lands and jungle scrub of Ceylon, Burma, and India. These lively, yellow-green, sharp-billed, wren-like birds generally go about in pairs, building their nests rarely more than 5 feet from the ground in trees provided with long and rather broad leaves. The females are smaller than the males. Both, when out of the breeding season, have short tails and present a "bunty" appearance, but during nidification the male grows a remarkably long tail which he flirts about with great effect and takes

on all the airs and graces of the true wren, rapidly sounding his clear double note, "te-weet, te-weet," so that all the world may hear.

Except as a wedding garment one can hardly understand the use of the long tail of the male *sutorius*, especially as he is a good husband and takes a great interest in the raising of the family. When it is his turn to sit on, or in, the pocket-like nest he presents a most curious appearance; his long tail must perforce be applied all along his back so that it and his beak almost meet, surely an uncomfortable position for a long siesta.

When she (because only the female bird constructs the nest) can find them, the tailor bird prefers certain favorite trees for building her nest. Among these is the so-called lettuce tree, *Pesonia alba*, from the appearance of its pale yellow foliage and because the leaves are sometimes used as a salad. This is a small evergreen from 25 to 30 feet high. Dracœna and other umbrageous trees are also utilized.

If the tree chosen has very long and large leaves the bird may be satisfied with a single leaf, or at most two leaves; if the leaves are of medium size or small a larger number are sewn or riveted together.

Dewar, in his work on Birds of the Indian Plains, details the construction of a nest by the tailor bird from a single leaf, as witnessed by Mr. A. G. Pinto. Some of the operations he describes are quite apparent in the Sigiriya nest, some are not.

> The first thing she did was to make with her sharp little beak a number of punctures along each edge of the leaf. Having thus prepared the leaf, she disappeared for a little and returned with a strand of cobweb. One end of this she wound round the narrow part of the leaf that separated one of the punctures from the edge; having done this, she carried the loose end of the strand across the under surface of the leaf to a puncture on the opposite side, where she attached it to the leaf, and thus drew the edges a little way together. She then proceeded to connect most of the other punctures with those opposite them, so that the leaf took the form of a tunnel converging to a point. The under surface of the leaf formed the roof and sides of the tunnel or arch. There was no floor to this, since the edges of the leaf did not meet below, the gap between them being bridged by strands of cobweb.
>
> When lining the nest, the bird made a number of punctures in the body of the leaf, through which she poked the lining with her beak, the object being to keep the lining *in situ*. All this time the margins of the leaf that formed the nest had been held together by the thinnest strands of cobweb, and it is a mystery how these can have stood the strain. However, before the lining was completed, the bird proceeded to strengthen them by connecting the punctures on opposite edges of the leaf with threads of cotton. Her *modus operandi* was to push one end of a thread through a puncture on the opposite edge of the leaf. The cotton used is soft and frays easily, so that the part of it forced through a tiny aperture issues as a fluffy knob, which looks like a knot and is usually taken as such. As a matter of fact, the bird makes no knots; she merely forces a portion of the cotton strand through a puncture, and the silicon of the leaf catches the strands of cotton and prevents them from slipping. Sometimes the cotton threads are long enough to admit of their being passed to and fro, in which case the bird uses the full length.

I may say, in passing, that I have never known the tailor bird—unlike the architect of the quite as wonderful weaver bird's nest—to breed in captivity, or to make a good cage or aviary pet.

To return to my treasure trove—the nest at Sigiriya—it occupied a position in the very center of the Sapu, 4½ feet from the ground. It was made of three long, lanceolate, horizontally-placed leaves, measuring respectively 12 by 3 inches, 13 by 3¼ inches, and 12½ by 3 inches. It measured quite 3 inches at the widest and 2½ at the narrowest diameter. The whole nest took the form of an irregular cornucopia. The cup cavity was lined more or less completely for a distance of 7½ inches from the tip, thus leaving about 2 inches to the free edge of the horn. The lining of the nest varied in thickness, but was quite half an inch in some sectors of the cornucopia. The material used in upholstering the nest was mostly the cotton-like material taken from a neighboring species of Euphorbia, whose seeds are provided with a closed umbrella-like tuft of soft, shiny fibers. There were in addition a few threads, some dried grass, coconut fibers (probably from the house mats), two small feathers, and some black hairs. The last named were probably from bullocks as no horse had been seen in Sigiriya for over a year. There was also among the lining materials some kapok, or native tree cottons, the silk cotton tree (*Ceiba pentandra*) and red cotton tree (*Bombax malabaricum*). Both those flosses were available in the neighborhood and are much used by birds for lining nests.

The solidarity of the nest as a whole was increased by the arrangement of the fibrous material in the lining, the coconut fibers, dried grass, and feathers being interwoven to form rings or bands that ran around and were fitted into the interior of the cornucopia, the cotton floss lining the cup cavity and padding the space below it.

Most writers on the subject speak of the act of sewing as the chief means employed by the tailor bird on the leaves that cover her nest, but there were (as will be seen) but few signs of this method in the Sigiriya nest. Close investigation of the free end of the leaf pocket shows that a shred of fiber from the cotton mass had been drawn through each of the small marginal openings and that these strands had spread out as dot-like buttons on the exterior of the leaf, preventing the cotton from slipping back. In this way the margins of the leaf had been drawn together by a sort of cross-riveting, that also welded leaf edges, nest lining, and the cotton mass together as one whole. The same process is seen all over the outer surface of the joined leaves.

The bird makes with her ¾-inch bill a puncture in the leaf, grasps a strand of nest lining, pulls it out through the small opening until the mass of which it forms a part is firmly drawn against the inner surface of the leaf. The external cotton then expands and forms a

minute button that effectively holds the leaf and nest contents in close apposition. When the riveting has been repeated, as in 75 places on the Sigiriya nest, it holds firmly. In this nest the Euphorbia cotton made excellent rivets for holding the leaves in position.

The Euphorbia pod is filled with seeds attached to a small plume of compressed floss. When the seed is detached there remains a minute umbilicus that holds the cotton fibers together. It was frequently this coherent plume whose seed the bird pulled—end on—through the opening made in the leaf. Once through the aperture it expanded and held in place the remainder of the cotton, with its attachments to the nest lining.

If we number the three leaves that formed the casing of the nest, leaf I had by careful count 20 holes through which a tuft of cotton had been drawn, while 9 had been unused. Leaf II had 25 filled and 9 unoccupied perforations; while leaf III had no less than 31 filled and 14 empty holes.

Where the leaf edges touched, the perforations, both filled and unfilled were placed a quarter of an inch apart. These marginal holes were more numerous, as in the body of the leaf, on leaf II and leaf III, the latter showing 8 filled and 5 empty perforations, while the former had 5 occupied and 8 unoccupied.

It may be said in explanation of the manner in which the female tailor fashions her nest that there are four distinct processes employed in binding together leaves and nest—sewing, rivetting, lacing, and matting.

The nearest approach to sewing occurred in three or four instances when the out-drawn strand was not that nearest the perforation but was seized beneath the farther leaf and riveted into the neighboring leaf. Such an arrangement gave the appearance of stitching the edge of one leaf to the margin of the other. This appearance may be seen in one of the photographs.

In one of the earliest descriptions given of the tailor bird's nest, Jerdon, a most acute and careful observer, says the bird makes a knot in the silk or cotton to keep it in place. Now, the most minute survey of the external surface of the three leaves fails to show the slightest approach to such a device, and it may be added that the expanded, button-like process in the instances described seemed to anchor the nest mass as effectually as if it had been tied in a regular knot.

The second nest of the tailor bird was made from a single leaf. This was the one presented to me by Captain Phillips, of Kitulgala, Ceylon, August 1, 1925. He found it, June, 1925, in the middle of a croton bush, 3 feet from the ground. It is evidently an unfinished nest and in early stages of construction, but shows very plainly the processes commonly employed in nest building. The leaf itself is 8½ inches long and 8 inches at its widest part. The interior

measures 2¼ inches in diameter at the rim, tapering to the end so that the length of the unoccupied cup is about 6 inches. It was built in one of the large, broad, yellow-blotched, cordate leaves of the parasitic creeper, *Pothos aureus*, or "Colombo agent." This epiphyte was introduced from the Solomon Islands and is now quite a common plant in Ceylon.

As shown in the photograph, the bird has made 16 perforations on the edge of the left half of the leaf, none of them more than one-quarter of an inch from the margin; there are 17 holes on the other edge. These openings were placed within 4½ inches of the edge on both sides—leaving free borders above and below. As shown by a powerful glass, about one-half the perforations on either side are occupied by threads of various sorts. From above downward three perforations on one side and four on the other were drawn together by a single fine fiber that was firmly attached to the leaf margin by winding it around the free border of the leaf. The very thin thread at first appeared to be spider's silk, but a close examination by means of the lens and a dissecting needle proved it to be a much stronger fiber—like that of an agave or a disintegrated coconut fiber. This web-like thread was then passed five times across the interval in the upper borders of the apposed leaf edges, and firmly anchored at the four openings by winding it in and out around the leafy bridge made by the perforation near the leaf margin. To consolidate this part of the interlacing a sliver of dried grass was worked in (see the photo) across the intermarginal opening.

At this point the two leaf edges overlap, and the next four openings are superimposed so as to allow the passage of small shreds of cotton, pulled through both holes and tufted down. Several grass and other coarse fibers were now placed beneath the overlapping leaf edge, and through two perforations in the latter are run strong threads that pass through the minute bundle of fibers to the opposite openings and back again—a combination of stitching and lacing.

The last two holes are held in apposition with the margins of the corresponding leaf edges by threads that were evidently drawn taut by a sort of pulley-like motion so that this apposition of the edges is as firm as any part of the stitching.

Constructed in this fashion the infolded leaf presents a remarkably regular horn of plenty with its rounded, outer surface presented to the observer, and showing no trace of tailoring that had gone on in the unexposed margins.

Captain Phillips thinks that occasionally these incomplete structures do not pass beyond the stage of invagination, but that the infolded leaf is used as a shelter for the bird awaiting his or her turn to occupy the near-by nest, just as some observers believe the weaver bird uses his "canopy" for the same purpose.

TAILOR BIRD'S NEST AS IT APPEARED IN THE MIDST OF FOLIAGE

TAILOR BIRD'S NEST, WITH THE SURROUNDING LEAVES REMOVED

PHOTOGRAPH OF A TAILOR BIRD'S NEST, TO SHOW THE METHOD OF RIVETING THE LEAVES TO THE NEST LINING

TAILOR BIRD'S NEST, SHOWING THE LINING OF COTTON, ETC.

TAILOR BIRD'S NEST MADE FROM A SINGLE LEAF. NOTE THE SEWING AND LACING

THE NEEDS OF THE WORLD AS TO ENTOMOLOGY[1]

By L. O. Howard

I have chosen an ambitious and rather sweeping title for this address. It would make a good title for a book. I may possibly use it as a title for a book I have been preparing for some time. It will serve my present purpose, however, to head some thoughts that have come to me after about 60 years of greater or less attention to insects.

Not so many years ago this would have been considered a mixed audience, an audience surely at one in that all are interested in entomology, yet mixed since it contains investigators whose sole aim is apparently the study of this vast assemblage of extraordinary forms of life in some one or several of its aspects from that ennobled curiosity which lies at the bottom of so much valuable scientific research—the effort to answer the continual questions "why" and "how"—and since it contains also investigators who are striving to overcome the agencies which are destroying many of the vital needs of the human species.

But now it is coming fully to be recognized by all of us who are working with insects that, while the man who is trying to supply *immediate* relief from great loss by the most *immediate* measures is the man for the *immediate* emergency, every man who studies insects and who records his results is doing greatly needed work and work that sooner or later will help to lead to a close understanding of insect life which may bring about its control by man.

I will not speak here of the rapidly increasing appreciation by the intelligent part of the public of the tremendous importance of entomological work; but of another fact, which is that, in spite of the good we have done and are now doing, month by month the insect problem becomes more serious. It is far more serious to-day than it was 20 years ago, although the workers in economic entomology have doubled in that time and the money expended in entomological investigations has probably trebled. It is enormously more serious than it was 50 years ago when a mere handful of men were laying the groundwork for our rapidly growing structure.

[1] Annual Address before the Entomological Society of America, Washington, December 31, 1924. Reprinted by permission from Annals of the Entomological Society of America, Vol. XVIII, No. 1, March, 1925.

This may look to the carper or to one who loves to chaff his entomologist friends as a possible case of cause and effect—the more entomologists, the more insects and insect damage! But to the knowing mind it is perfectly obvious that, just at the time when the crisis of overpopulation of the earth is approaching, just at the time when the total human food supply must rapidly be increased, the multiplication of injurious insects is helped in a way by the very methods man has adopted in his civilized life!

Instance after instance in illustration of this fact will occur to you. Let us look at the cotton boll weevil. Here is a species that gradually developed its close adaptations to cotton in Central America where the cotton tree grows wild. It was a nearly unknown creature of slight economic importance. Brought by accident across the Rio Grande at Brownsville, and then more or less by accident to Alice, it found itself in a boll weevil heaven—a whole State growing its favorite food, and growing it in just the way to make life a delight, in just the way to promote to the utmost limit its extraordinary powers of multiplication, and so its enormous progressive spread until now the whole vast Cotton Belt is occupied. Incidentally it may be said that all this might have been prevented had the advice of entomologists been followed in the beginning, and that at a later date the spread might greatly have been retarded and the damage very greatly lessened had the Southern cotton planters generally heeded the advice of the experts.

This will answer as an illustration in regard to agriculture. With regard to human health the same conditions hold. For example, it may be shown that the advance of civilization in a new country at first reduces malaria, by the drainage of swamp areas and the reclaiming of moist "bad lands" for agriculture, only to be followed, as the country becomes densely settled, by the reappearance of malaria, since man has made new and even better breeding places for the malarial mosquitoes than were the old swamps: the making of milldams, of stone quarries, the stopping of extremely small streams of running water by railway embankments, the digging of borrow pits, the accumulation of old tin cans and disused vessels of one sort or another about towns, even the footprints of cattle in soil that is not too dry, especially during a rainy season, and in countless other ways, such as water troughs for cattle, small ornamental ponds for aquatic plants, the water receptacles for grindstones, poorly-protected cesspools, imperfectly-covered water tanks, the catch basins of sewer systems, the badly-cared-for roof troughs of houses and barns, even the perfected and up-to-date water-closets in houses temporarily vacated, and so on and so on.

Attention has often been called to the increasing spread of injurious insects from country to country by the rapidly increasing speed of ocean voyages. Our latter-day Japanese beetle and European corn borer inspectors appreciate as can no one else how the hundreds of thousands of automobiles and our greatly improved roads help the spread of these and many other pests. As early as the peace conference at Portsmouth at the close of the Russo-Japanese War, when thousands of vehicles from regions infested by the gipsy and brown-tail moths brought their loads of sightseers to Portsmouth, there resulted an immediate extension of the range of these imported pests. And when T. Chalmers Mitchell and his companions attempted to fly from Cairo to the Cape a few years ago, the possibilities of the airplane as a spreader of insects was demonstrated, as I heard Mitchell state at a meeting of the Zoological Society of London in 1920.

So what is termed "advancing civilization" is not only encouraging insects to multiply almost beyond bounds, but it is facilitating and hastening their spread in many ways.

In the face of all this, what we have done and what we are doing, much as we have accomplished, especially during the past 20 years, is a trifle—a comparatively insignificant series of things done and learned compared to what we have still to do and to learn.

In the first place we must have the public behind us. The public must be made to appreciate the fact that it is a vital necessity to the future of humanity that we should learn everything about insects; that keen and highly trained men should be studying every aspect of insect life, and that chemists, engineers, plant physiologists, bacteriologists, and scientific men of many specialties must be called in. They must learn that the study of no aspect of insect life is a trivial pursuit, as their fathers thought, and they must learn that the entomologists are the men on whom the world must depend for much of its future prosperity.

This education of the public is going on rapidly, but we must help to speed it up. A number of strong writers in the newspapers and in the magazines have found the topic attractive and interesting. Many of us have grasped opportunities to address lay audiences of all kinds on the general subject, and all of us who can speak more or less forcefully in public must never lose a chance to drive this particular lesson home.

Incidentally there is an enormous opportunity in the teachers' colleges, in the great summer sessions of such institutions as the Teachers College of Columbia University in New York, for example, where 12,000 teachers from all over the United States come together

hungering for information to take back to their hundreds of thousands of pupils everywhere.

Many of you may have noticed that a committee "on the place of the sciences in education" has been constituted by the American Association for the Advancement of Science. This committee includes representatives of high schools as well as of universities and others. There is a place under this committee for the consideration of secondary school science. In an article by Dr. O. W. Caldwell, in the journal Science for December 12 last, there is much information regarding the teaching of science. A significant table, for example, is given of the distribution of over 47,000 high school pupils in Washington in the different subjects in which they were enrolled. Of a total of 6,332 in science, 1,061 were enrolled in zoology. Here, obviously, is an opportunity for the stressing of the duty of teachers to include work in entomology, and the representative committee in charge of this subject should add an entomologist to its members as a preliminary step to the securing, not only in high schools, but in secondary schools as well, of such instruction in entomology as will arouse the interest of boys and girls in entomology and make them realize its enormous importance.

I am perfectly aware that what I have just said may sound as though it were intended for economic entomologists only, but I must emphasize again and again that there is no entomologist, whatever his line of work, who is not concerned and who is not helping very greatly.

Next to the education of the public, the number of workers must very greatly be increased; and public education will undoubtedly lead to this increase, since, by the stimulation of the interest of the people, the minds of capable young men and young women will be open to the call for service, funds will come from legislative bodies, and the way will be opened.

With the education of the public should come (and I hope it will) a great increase in the number of so-called amateur entomologists. We all know that men of this class have done magnificent work in the past; that in fact they did the bulk of the work down to comparatively recent years, and that they still constitute a very large percentage of the numbers of most of the great entomological societies.

How many so-called entomologists are there now? It is difficult to say. In the last edition of Cattell's "American Men of Science" there are approximately 9,500 names. Of these, 217 are recorded as entomologists. I have recently estimated the number of members of the large publishing entomological societies of the world and find that they probably reach over 6,000 and of these more than 2,000 are American. This latter number must be reduced, however, on

account of the fact that so many individuals belong to two or more of our societies—notably the Entomological Society of America and the American Association of Economic Entomologists. In the 1924 edition of Cassino's Naturalists' Directory, which includes all kinds of collectors, teachers, and so on, there are approximately 4,450 names. I have checked the names of those indicating any interest in entomology and they number 923.

But this stimulation of popular interest must go farther than the man in the street—the average citizen; it must uncloister our schools and colleges, not alone the minds of the students, but especially the minds of the teachers. The insect complex should receive the prime attention of a vastly greater body of trained research men in the universities.

In my presidential address before the American Association for the Advancement of Science in December, 1921, I stated that I had examined the titles of theses for doctorates in American universities for the preceding eight years and found that only a very small percentage of the output "represents work which can be of the slightest use to humanity in its immediate problem regarding the insect world, and, even those which may prove of use, bear some evidence that the lines of study had already been adopted by students who used them incidentally to gain their degrees and were not suggested by their teachers as promising lines leading toward some great practical outcome."

I have recently examined the titles for theses for the doctorate degree in American universities for 1922, and find that of 442 such theses 39 concern zoology. Of these 39, 19 were concerned with insects, which is apparently an improvement on the earlier situation; but of these, 5 were papers on genetics in which Drosophila was used, and only 6 of them had any apparent economic bearing. The other 8, however, represented good, sound work, and the results of the investigations on which they were based undoubtedly will help in our broad aim to understand the insect class.

Dissatisfied as I am with this small proportion among the zoological theses, I am naturally equally disappointed in the small proportion of theses that concern any aspect of zoology, and I am disappointed at the small number of all of the theses for doctorates. The time is coming—and we must do all that we can to hasten it—when not only will research students be at work in our universities in much greater numbers, but when those applying themselves to entomological subjects will be multiplied many times.

In this broader training of the coming workers in entomology the latest conceptions in biology and the latest methods will become known to them and will influence their work. We see this coming

rapidly to-day. The mathematical trend in biological work has not been sufficiently noted by many entomologists. We can not afford to neglect this movement. If we do neglect it we will lose the significance of much of the research literature of biology, and in our own work will lose the good to be gained from these mathematical methods.

This has naturally led up beyond the discussion of the needed increase in numbers among the entomologists into the need for broader and sounder training. And this in turn will lead us to a consideration of the direction of this research training and the vast opportunities which exist for the most important research. To do this properly we must know comprehensively where we stand to-day.

In morphology we are most fortunate at this present moment to have at hand (only a month from the press) that magnificent "Introduction to Entomology" by Comstock, its thousand pages displaying this side of entomological accomplishment to date, the result of long years of close and careful work by a great student and teacher.

I have used the term "morphology," in referring to this great work, as including external and internal anatomy and taxonomy. Physiological information occurs frequently in the consideration of anatomical points, and embryological data are touched upon here and there. In the consideration of metamorphoses also the treatment is broad beyond the usual understanding of the term "morphology;" and habits, behavior, life history data, and points suggesting ecological work are touched all through the bulk of the book. So in a big way this "Introduction" is much more than an introduction to entomology; it is an introduction to the new entomology that is to come. We may take it as a starting point from which to proceed, just as the older entomologists took Westwood's famous "Introduction" and, later, Sharp's "Insecta," and as the men of the generation of Walsh and Riley and Thomas and Le Baron took the classic "Insects Injurious to Vegetation" by our own Thaddeus William Harris.

Before leaving the subject of morphology, attention should be called to the advanced and most competent work of Snodgrass, some of which is already available and much more will soon be available. Comstock's mention of the work of this gifted entomologist, on page 205 of the new "Introduction," is a deserved and gracious act of the veteran.

I think that the subject that has been most in the minds of many of us in recent years has been insect physiology. After scores of years of work by brilliant men, our knowledge of the physiology

of the human species still has many gaps. How much more, therefore, with its pitifully small number of workers, is there to be learned about insect physiology! Fundamentally radically different from the vertebrate structurally, how importantly must their physiology differ! And upon their physiology as greatly as upon their structure must their behavior depend. In the main, we know what they do only as it affects our interests. We must know everything that they do and why and how they do it. Here physiology is basic. To understand their reactions, to be able intelligently to explain their tropisms, we must know how they direct their movements, how they communicate, how they hear, how they see, how they digest their food, and the scores of other things upon which a complete knowledge of their physiology would throw light.

I think it is quite certain that this is the largest as it is surely the most important of the comparatively unexplored fields in entomology. What information there is exists in scattered papers in many languages, and many of the investigations in so-called physiology are really little more than studies of internal anatomy in which the histology of organs is considered from a more or less comparative point of view. Enlightening work has been done on the structure of the sense organs, notably that of McIndoo on the olfactory organs of insects of several different orders. But physiology in general from its experimental and chemical aspects has hardly been touched. Such studies as have been made are not assembled so that we can readily know where we stand. Although the first part of Packard's text book is entitled "Morphology and Physiology," and covers over 500 pages, it is almost wholly anatomical, and it is 26 years old.

One of the greatest and most important fields in human physiology and in that of domestic animals, and one which is being most intensively worked, is that of nutrition. What do we know about the food elements necessary to insects? And just how is this food utilized? Here is a field which is crying for investigation by the best trained men, using the most advanced methods and able, in fact, to invent new methods—men of the genius of Krogh, of Denmark, for example.

As already indicated, upon our knowledge of the physiology of insects must depend our understanding of their tropisms, and upon a clear understanding of these tropisms will depend many of our future methods of warfare.

When we speak of tropisms and behavior we are touching upon what stands for psychology with insects. Recently, in the World War, we have had a striking example of the enormous handicap to

a battling nation of a lack of understanding of the psychology of its antagonists. It is a far cry from the varying psychology of the different races of human beings to the vastly different psychology of insects. But how important it is to attempt at least to understand such psychology as they possess, and how little do we know about it now! But we have a beginning, Bouvier's admirable "La Vie psychique des Insectes" brings together what we know now, and therefore forms a starting point for experimental work and study which may lead to important results.

The psychology of insects, of course, brings us at once to the disputed borderland of instinct and intelligence. We are none of us ready to adopt Ferenczy's classificatory name for the human species (*Homo immoralis semisapiens*) as contrasted with his ant name (*Formica sapiens diligens*), nor do we misunderstand Wheeler's exquisite satire on human society which he entitled "Termitodoxa," but, for want of a better name, we may call psychological a lot of insect phenomena which need investigation.

Insects are controlled by nature very much better and more effectively than by man himself—assuming that man's efforts are not a part of nature (as they surely are, since man is a true ecological factor). Many more insects are destroyed by their parasites of different kinds and by their other natural enemies than are destroyed by man. In fact, man has really been making things easy for the insects—he has been facilitating the multiplication and spread of his own worst enemies, and at the same time he has been groaning and complaining and suffering from the effects of his own stupidity.

The trite words "going back to nature" have an especial significance in this connection. We can not go back to nature, in a way, if we wish to preserve our rank as the dominant species and still keep on increasing all the time. We must continue to "upset the balance" and keep on upsetting it more and more if we are to feed our increasing millions. We must control all possible food resources. But we must get back to nature in so far that we must study all these natural control factors as they affect antagonistic species, and we must utilize them.

But to utilize them we must first understand them, and the word "understand" does not mean half knowledge. Generalizations are nowhere more dangerous than here. I have been studying some of the smaller aspects of this subject for more than 40 years, and I have seen my imagined or expressed generalizations fall by the dozen through the work of keen-eyed and competent younger observers. And yet the enormous complex of interacting organisms, really fight-

ing desperately among themselves, is only just becoming apparent, and offers a field for many keen workers for many years to come. And it is a field of very great promise. It is one of the fundamentals.

The complexity of the problem is growing on us. What we once thought simple becomes the more involved the deeper we go into the subject. But these very complications as they arise should only render the subject the more attractive to the truly scientific mind. Nowhere do we run up against a stone wall; but the more we observe and the more we study, the more the field opens before us and the closer we come to a true understanding of relations and the more apt we will be to find principles and ideas that will be of value from the human standpoint.

Insects are a healthy race. They have in these 50,000,000 years bred out the unfit. And their very prolificacy more than compensates for the losses caused by occasional epidemics. But in the study of natural control, insect pathology, a largely neglected field, must have more workers. We must know here, just as in every other possible line of insect research, every fact that can be ascertained. Of course, the insect pathologist will be working for an end diametrically opposed to that of the human pathologist, but the basic technique of the latter will help the former, and the causative organisms of disease have a certain zoological or botanical grouping which will render the work of both groups of pathologists at least comparable. There are great gaps to be filled in our knowledge of the forms of parasitism in which protozoa, bacteria, fungi, helminths, and filterable viruses are concerned.

In this direction the work of Pasteur on pebrine stands out, and the results of subsequent investigations of this disease have been incorporated in a number of papers, especially by Italian investigators. The diseases of bees have been investigated by our own G. F. White and A. P. Sturtevant; and Burri, of Switzerland, Bahr, of Denmark, and Maassen, Bochert, and Zander, of Germany, have contributed to the study of bee diseases. Kudo, of Japan, has worked upon the protozoa of insects, and a number of medical investigators have been led to study the microorganisms in the digestive tracts of insects that bite man.

Paillot, of France, is making profound studies of the microorganism fauna of the insect body. Metalnikov, of the Pasteur Institute in Paris, has been working on the blood of insects and making studies relative to the problem of immunity, using largely the larvæ of the wax moth. Rudolph Glaser and G. F. White, of the United States, are studying the pathology of insects.

Nearly all of these workers, however, have spent only a portion of their time upon such studies and have each contributed only a few papers. Systematic, consecutive, well-planned work by many men, perhaps in cooperation, must be brought about.

From the fact that certain disease organisms inhabit both insects and warm-blooded animals and that with some of them this dual host relation is a necessity in their lives, we are led to the subject of medical entomology.

It seems to me that no wise man can for an instant believe that medical entomology has passed its infancy. To all intents and purposes this branch of knowledge was first opened up less than 30 years ago. Its increase has been dramatic. Three years ago, at the invitation of the president of the American Public Health Association, I wrote the "Sketch History of Medical Entomology." It was a subject with which I had been connected since its beginning. It was a subject of vital interest. Discovery had followed discovery with such rapidity and the results which followed these discoveries were of such enormous importance to humanity that the story fairly wrote itself. The subject has developed so rapidly and has spread out in so many directions that it invites and in fact demands the keen attention of many workers.

It is true that most of the main discoveries have been made by medical men, but all future work demands the intimate cooperation of pathologists and entomologists. The control of an insect-borne disease, whether of man or domestic animals or cultivated plants, means primarily the control of the vector; and who so competent to investigate the possibilities in that direction as the man trained in economic entomology?

Not so many months ago, traveling for a day or two in the company of the principal officer of one of the great medical research institutions, I suggested to him that a well-equipped service should be started, preferably at some great scientific center, where the intimate biology of all insects known to be carriers of disease should be investigated by competent men, untrammeled in their work and assisted to the limit of their necessities in a financial way; that these men should include in their investigations not only all known vectors but all of the close relatives of such species. I am sure that my suggestion was sound; that the establishment of such a laboratory or series of laboratories is a great desideratum; that the results to be gained by such work could not fail to be of very great benefit; and I, therefore, advanced the project with some assurance. To my disappointment, however, it was received with an interest which was obviously only a matter of courtesy, and I dropped the subject in discouragement. But why should not such a plan be pushed? Let

some man yet in his forties draw up a scheme in as much detail as possible; let him consult with his wisest associates; let him look over the field with a prophetic eye; and then push the plan with an enthusiasm and energy which belongs rather to the fourth decade of life than to the sixth (now occupied by the writer). Of course, it is quite possible that this idea may not be adopted, but in the very outlining of the plan it will be necessary to bring together all the sidelights with the main idea, and out of it will come unquestionably a stimulation to research of the broadest kind in this vital direction.

And now we come to ecology. Originating as a name not so long ago among the botanists, this term has broadened in its significance to include certain aspects of the whole biological field.

In his masterly address delivered before this society in 1915 entitled, "The Ecological Foundation of Applied Entomology," that deep and sound thinker, that broad naturalist, that man whom this society and our sister societies have been proud to honor as the dean of the economic entomologists of America, Dr. S. A. Forbes, pointed out in his clear and forceful way that nowhere does the broadening of biological studies into the field of what is now termed "ecology" promise better results or greater opportunities than in applied entomology. In fact, he says, "The economic entomologist is an ecologist pure and simple—whether he calls himself so or not * * *." This wonderful address and the contemporaneous and subsequent writings of Shelford and others have opened the eyes of many workers—in fact, have made many productive workers—and all leaders of main projects having insect control in mind are now looking upon their problems with ecological eyes.

The revolution which has come is well illustrated, for example, in the October, last, number of the Canadian Entomologist, where the leading article, by W. C. Cook, tells of a study of the noctuid moths caught at light at Bozeman, Mont., in 1919 by K. M. King and in 1923 by himself. Even a dozen years ago the moths so caught, if they were good specimens, would have been pinned, identified, and put in the college collection or in a private collection, accurately labeled, of course, with date and locality, and there the matter would have rested. But with our present growing knowledge of the factors concerned in the ecology of insects and the importance to be placed upon an accumulation of individual notes, Mr. Cook has gone far: He has analyzed the results, taking into consideration the food plants and habits of the species involved, the question of temperature and rainfall and elevation and character of the country inhabited by

the individual species, and has been able to draw from all this the following conclusion:

> The insect fauna of a given region is not a single stable unit, varying only in abundance from year to year, but is a composite of smaller groups, each of which has more or less definite optimum. The composition of the fauna in a given season is very definitely related to the climatic conditions prevailing at the time of growth. Three dry years culminating in 1919 enormously increased the proportion of prairie elements in the Bozeman fauna, while reducing the eastern and mountain forms. The trend of the climate toward normal has resulted by 1923 in a great reduction in these prairie intruders, and the reestablishment of the eastern and mountain forms. How much farther this movement will go can not be predicted, but it is certain that a return of dry weather will reverse the direction of the trend.

I select this instance because it concerns a paper that was published only the other day, but recent entomological and ecological journals contain numbers of articles of equal or greater significance. What an advance! In the general warfare against insects those conclusions will seem to have no immediate bearing upon any problem, but they are valuable and very suggestive and indicate great progress in entomological thought and methods.

I find a confident prophecy as to the effect of work of this character in a paper by C. H. T. Townsend in the journal Ecology for January, 1924. He says in closing:

> Environment work will be the first and last steps in the insect control of the future. The normal favorable environment must be changed to an unfavorable one. Given the factor values in the environment classes to which the insects' phases are subjected, with the insects' responses to the same, we are in the most advantageous position for deciding which phase to attack and which environment class to manipulate in order to gain control.

Here the factor values include heat, sunlight, rainfall, atmospheric humidity, atmospheric pressure, wind, soil texture, soil moisture, vegetation, food supply, predators, parasites, and disease.

I remind you of this prophecy without absolutely complete indorsement, but as an especially notable paragraph.

We must not leave this subject of ecology without mention of Hopkins' promising work on bioclimatic laws. It is a subject to which this able thinker is now fortunately able to devote his principal attention. He has already arrived at conclusions of far-reaching value—far beyond the confines of economic entomology—and it is hoped that this great work will receive the appreciation it deserves.

To be able to know precisely and definitely what creature is before one—to be able to write about it in such a way that all other workers will understand—necessitates a system of classification and the naming and technical description of a host of forms. The comparative study of morphological characters, of course, indicates relationships,

presupposes similar methods of development and similar behavior among the related forms, and in addition it affords evidence as to lines of descent and the general trend of evolution.

In spite of the hundreds of thousands of species of insects that have been named and described, a greatly larger number remain unnamed, while the stability of the names already adopted and of many of the classificatory details and systems has by no means become fixed, and there is a sad lack of comprehensive catalogues of groups—a type of publication of the greatest use to all entomologists. There is, therefore, a crying need for many more capable taxonomists.

Further than this, there is also a crying need for bigger and broader taxonomists—for the men now at work to become bigger and broader, and for the men entering the field to consider a host of things unconsidered in the old taxonomy. The average taxonomist of to-day is lagging behind in the advance of science. New species continue to pour in at such a rate that his time is constantly occupied with descriptive work. He is seldom able to apply himself to an extended revision of a given group, and if he does attempt such a revision he fails to consider even the small amount of work that has been done in internal anatomy, embryology, physiology, and paleo-entomology. His system can not be absolutely sound, because he is not able to go deep enough. We need a sounder and better based classification all through the group "Insecta," and this is one of our prime needs to-day. The basic value of a stable nomenclature to all workers in all phases of entomological effort, applied or not, needs no argument here; it is obvious to all of us who are engaged in economic work; it is obvious to those who have done work in embryology, morphology, genetics, or any other branch of biology in which insect material is being used.

Taxonomy with the class "Insecta" is complicated beyond that of most other groups of animals by the existence of complete metamorphoses and the radical difference in the lives of the larvæ and of the adults; a fact which brings to bear on each stage many evolutionary factors entirely different from those acting on the other. This demands the consideration in taxonomy of what we used to call "life history work," and it is in this life history information and in exact knowledge of early stages that there are very great gaps. Fortunately, the work on the life history of any one species or another is fascinating, and always attracts workers. The number of such investigators is increasing rapidly, and gaps are being filled.

We are sadly lacking, however, in our knowledge of larval forms and in our ability at once to identify larvæ without first rearing the adults. In practical work, and especially in international or intersectional quarantine, the most comprehensive knowledge of larval forms is necessary, since in the operation of commerce insects are carried accidentally quite as often in the larval form as in the adult form.

Work upon larval stages is going on at the present time with some groups of lepidoptera, certain diptera, and the coleoptera. Perhaps the most ambitious effort of this kind is that with the last-named order. It is a great pleasure to know that Böving and Craighead have almost finished characterizations, keys, and short diagnoses of the families and subfamilies of the entire order coleoptera.

And, speaking of quarantine work, we should not only be able to identify material found in whatever stage, but there is a great deal that should be known which does not come properly under this portion of this paper. It is becoming plain that quarantines may be promulgated which are unnecessary. We have been obliged to go on the presumption that a pest in a given country may be and probably will be a pest in another country; but such a decision can not be made with full justice without a knowledge of the ecology of the species in its original home. It would virtually be impossible for any nation to carry out investigations of this kind within the territory of another nation for any number of species without international agreements and without the expenditure of large funds, but, if we had known, for example, in this country, in advance of the advent of the European corn borer, the ecological facts concerning this species in Europe, which Mr. K. M. Babcock is at present studying over there, we would have been in position to attack the problem, perhaps not much more confidently, but with a more exact idea concerning the possibilities of spread.

Cooperation is the keynote to success in all great undertakings. (Pardon this trite statement, tritely put!) In this effort to gain a perfect knowledge of insects and, through this knowledge, to control them, we are engaged in one of the greatest of all undertakings; and it is not alone for the benefit of our own people—it is for the benefit of humanity. Therefore, in this great effort let us never forget that we must freely urge the help of men working in other branches of science—that we must be keenly on the lookout for points where they can help us—that we must plan our investigations with the idea that others will help, and we must call them in consultation in making our plans.

For many of the needed types of investigation we as entomologists must train ourselves to be self-reliant, but as we broaden out we must beg the help of experts in many different lines. Any one of the many discoveries being made in physics, chemistry, or other sciences may touch or may be made to touch our investigations looking toward the control of insects. Some discovery now on the point of being made in one of these sciences may lighten our task.[2]

Primarily in agricultural entomology must we consult the wisest experts in farm management—the clearest-thinking agronomists. We realize, as I have already pointed out, that with many of our methods of farm practice we are encouraging the multiplication and spread of many insects; we are fairly inviting them to overwhelm us. Why waste years of work trying to fight them in one way or another under existing conditions if it be possible, after a full understanding of their ways, so to vary crop methods as to hit a vital point in their economy without materially lessening crop production? This has been done in a number of instances. Only the other day one of our English colleagues (Frew) advised a slight and inexpensive variation in the manuring and cropping of barley, which will do away with the damage by a serious insect enemy. A careful study by an expert agronomist of the life-history facts already learned by us about a number of our principal injurious insects will undoubtedly lead to valuable ideas and to the indorsement, from a far-seeing practical side, of suggestions in this direction which some of us may have made.

There is no scientific man whose cooperation the entomologist more needs than the skilled organic chemist. There are scores of problems of great importance to which the labors of such a man or men should be turned. In the chemistry of the physiological processes in the insect body he is needed, and he is especially needed in the study of the chemistry of the plants upon which insects feed, in the effort to understand fundamentally what there is about certain plants that attracts certain insects. For many months, now, that famous investigator, Dr. Frederick B. Power, with the able assistance of Mr. V. K. Chestnut, has been studying the chemistry of the cotton plant, and this is being done on a scale and with an expenditure of time and care never before equaled in such a study. The results already obtained have been of the highest interest from the chemical point of view, and also from the point of view of plant structure and physiology; and there have been developments which may prove to

[2] Mention may be made here of Prof. C. K. Brain's just-announced discovery in South Africa of the adaptation of certain radio principles to insect investigation in which he shows that by the use of microphones the presence of insects may be determined, not only of wood-boring insects, boring in wood, but of insects in stored grains.

be of great importance to the economic entomologist. It would not be proper for me to make more than this mere statement, but a preliminary paper is being prepared which will contain many astonishing facts.

The Chemical Warfare Service of the Army is carrying on an elaborate series of tests against insects with different gases, and has a great accumulation of records which when published will be of undoubted value if only as records. These tests, in the main, have been made in cooperation with the Bureau of Entomology. There is an exception in the case of tests against the cotton boll weevil, for which a direct appropriation was made to the War Department on the initiative of a southern Senator. Even the tests from which there have been no obviously valuable results will have an ultimate value to future experimenters. It is, therefore, to be hoped that the secrecy which necessarily must surround Army experimental work with poison gases that may be used in warfare will not prevent the near publication of a record of the exact experiments of the Chemical Warfare Service against insects.

It is true that certain other chemists have entered this field. George Gray, of California, has a large manuscript on the chemistry of insecticides, not yet published, but he has been drafted into the service of the State in a somewhat different capacity and is no longer able to devote his whole time to this important side. William Moore, from whom we expected and still expect great things, has joined a commercial organization. There is this to be said for chemistry, that industrial corporations are employing numbers of research men and that therefore the very research which we need may be and is being supported financially by such organizations.

We must look to the chemist for the development of the most perfect insecticide, which as likely as not will be a synthetic organic compound. We must look to him for that greatest desideratum—a cheap compound that will at once stimulate plant life and deter or destroy insects.

There has grown up in these past years a beautiful spirit of cooperation among the entomologists all over the world. I doubt that such a spirit exists among the workers in any other branch of science. Each one of us has held himself in readiness to be of assistance to any one of his colleagues of whatever nationality. But we must not be satisfied with this. The needs of humanity demand both a broader and a closer association. The prime insect pests of the world are, through commerce, as we have shown, becoming widespread, and the self-protection of nations demands the most intimate knowledge of the injurious insects of all countries, since all

of them are potential pests of other regions. This subject was considered at some length at the recent Pan-Pacific Food Conservation Conference, and one of the resolutions adopted at that conference recommended the appointment of an international crop protection committee to promote surveys, to encourage research work, to promote the development by each country of larger numbers of trained workers, and to obtain agreements and understandings between countries regarding the giving of prompt notification of the appearance of new pests and to secure the cooperation of countries in the prevention of spread.

All these points that I have considered will no doubt be sufficiently obvious to you, and very possibly have been in your minds. There is a host of lesser suggestions that may be made, our needs are so very great. But this is not the place to go into an extended category of lesser things.

As I come to this point I realize more than ever that I have been writing all the time as an economic entomologist. Down to very recent times there has been a class distinction between the economic entomologists and the other workers, especially the taxonomists of the museums and workers in many laboratories. As the field has widened out, as the seriousness and vastness of the situation confronting humanity becomes apparent, these workers have been coming closer together; the economists have felt the importance of the labors of the others. The vastly greater part of the work of the economist has not been basic; it has consisted largely of an effort to apply known facts to special problems. The emergencies confronting him have been so great that he has had no time to conduct the long investigations that might give him other weapons than those nearest to his hand. His fight has been so strenuous that in a way he has lost his perspective.

But he has done magnificent work. He has confronted many difficult situations with success, and with simple weapons. But the great basic principles which have brought about the conditions which he has been called upon to meet have not been considered by him in his haste for immediate relief measures. He has available no more than a superficial knowledge of the forms he is trying to fight. It is true that he has carefully worked out in a more or less general way the life histories of many of the crop pests, but beyond that he knows little of what must be known.

I have just stated that he has waged a good fight "with simple weapons," but this must not be taken in a derogatory way. An admirable book, which (patriotically) I wish had been written by Americans, was published in England in 1923 by R. A. Wardle, of the University of Manchester, and Philip Buckle, of the University

of Durham, which gives a review of an advanced and encouraging character of our knowledge of "the principles of insect control."

It so happens, to consider things concretely, that an appropriation bill now before Congress allots for the fiscal year beginning July 1, 1925, more than $2,500,000 to the Bureau of Entomology; but of this large amount more than $1,200,000 must be spent on the three specific problems of the gipsy moth, the European corn borer, and the Japanese beetle, in the effort to prevent their spread and to gain at least partial control. And the remaining sums are for the most part to be spent in the study of special crop pests. In other words, at least half of the amount, although it may be continued in future years and will probably be so continued, should really be termed emergency funds—funds appropriated to meet immediate and specific emergencies.

It is an interesting thought that, looking toward the future, this large sum would probably be much more productive in the long run if it were spent in the effort to learn fundamental things along some of the lines we have touched. If this idea seems overdrawn, in view of existing conditions, it is none the less surely true that large sums must be forthcoming to support these greatly needed lines of research.

Last winter, toward the close of the Cincinnati meeting, I felt growing within me a conviction that we are on the eve of startling discoveries in economic entomology. I spoke of this to several leaders, and found that they shared the feeling. The conviction has been growing since, and may well be realized. But this does not lessen the certainty that it is our duty to labor diligently in our efforts to gain a complete understanding of insects. The comparative paucity of our present knowledge should be a tremendous incentive.

The entomologist has come into his own. He is acknowledged and respected by workers in other branches of science. The importance of his labors is recognized by the most important part of the general public. To justify this, and to increase it, demands that we work earnestly, that we make a strenuous effort to increase our numbers, and that we broaden our views and our methods.

FROM AN EGG TO AN INSECT

By R. E. Snodgrass
Bureau of Entomology, United States Department of Agriculture

INTRODUCTION

It is perhaps an inheritance from more primitive days that we are so prone to estimate value by size, and that we hold small things in contempt. Though we have learned full well from science that the most minute of living creatures may be vastly important or inimical to our welfare, we still persist somewhat in belittling the study of them. Especially is this true if the creature is an insect. Yet, the study of insects has contributed much to our knowledge of the general principles of life, and in particular to an understanding of certain phases of reproduction and heredity. This, because the fundamentals of life are the same for all living things, ourselves included, and because some life processes have been found more easily studied in insects and other lower forms of animals than in the more complex ones.

The microscope, however, makes the flea the equal of the dog, and on the printed page the discrepancy between the large and the small disappears, for the description of one may require just as many words as that of the other—and, we might add, words of equal size. Words! Words are the curse of scientific writing; but it should be recognized that any description is likely to be far more complicated than the thing described. If the object could be seen or pictured directly instead of being portrayed in words, how much simpler and clearer it might appear! We can not all, however, be students of nature at first hand, and it becomes a part of the business of the scientist to present his information to the public, or to such part of the public as is interested, and this he can do fully only through the medium of language. The true scientist, however, is usually so fearful of saying something that might possibly in some way be misconstrued by technical critics that he puts his statements in the terms adopted and defined by his particular branch of science. As a consequence, scientific vocabularies, while becoming more and more concise to specialists, are becoming less and less euphonic and

farther and farther removed from the understanding of the general reader. This state of affairs is to be deplored, because one of the purposes of science, at least of scientific institutions that employ scientists, is the diffusion of knowledge, and knowledge is not diffused by writings in which the secrets of nature seem to be just as carefully guarded from the public understanding as they are in the various realms of nature herself.

Another thing that contributes to the unreadableness of much scientific writing is the laudable desire of the scientist to give full credit where credit is due; but this often overloads his text with citations of references and authorities, and so breaks up the continuity of his account that the general reader soon tires in an attempt to follow it. What then shall we do? The only solution seems to be that for scientists we must write as scientists, for the general reader we must clear away all but the essentials, though letting it be known that we do not pretend to first-hand knowledge of more than a small percentage, if any, of the facts related.

In the following pages an attempt will be made to tell, with a minimum of technical terms, the story of the development of an insect from the germ cells to the creature at hatching. The facts of development and heredity, however, are exceptionally difficult to put into ordinary words, for the reason that they constitute phases of growth that are in many ways quite different from those with which we are more familiar. And yet, for descriptive purposes, things must have names. Therefore, where only a scientific name is available, that name must be used, and if the writer makes all possible concessions to a popular vocabulary, the reader, on his part, must agree to learn a few indispensable terms of technical embryology.

THE GERM CELLS

The materials of which living matter is composed consist mostly of substances that the chemists call unstable—which is to say, they are complex compounds that naturally break down into their simpler and more stable components. For this reason the physical substance of life must be continually renewed. All animals and most plants have a limited space of time during which they are able to repair their waste and remain alive. A large proportion of them, too, never attain their possible old-age limit, falling victims at an earlier age to other devouring animals, to parasites, and to diseases. Hence, even though each individual were capable of living forever, its chance of doing so would be slim; sooner or later it would almost certainly be destroyed in one way or another. To insure continuity of life,

therefore, the individuals of each species are endowed with the power of reproducing themselves. Some of the lower animals can regenerate themselves from pieces of their own tissues, but most animals procreate by means of special cells that have the property, under certain conditions, of reproducing a complete form like the parent. These special reproductive cells are known as the *germ cells*. Some of the germ cells of plants, called spores, have no distinction of sex, but in animals the germ cells are always of two kinds—male and female. The two kinds may be borne by the same individual, but ordinarily each is carried by a different kind of individual of the same species, and these individuals are accordingly distinguished also as male and female. The visible differences between male and female individuals, however, are mostly of a secondary nature, having a relation to the different demands of the germ cells on the individuals that mature them; the fundamental differences of sex are in the structure of the body cells themselves, which are distinguished by the same characters as are the germ cells.

The mature male germ cells are known as the *spermatozoa*, or sperms; the mature female germ cells as the *ova*, or eggs; but at any stage these cells may be called the male and female germ cells. Ordinarily the germ cells must be united in pairs of opposite kinds in order to produce new individuals. This kind of development constitutes sexual reproduction, and the union of the two cells is known as *fertilization*. In some invertebrate animals, however, including many species of insects, the egg is capable of developing alone, and development of this sort is distinguished as asexual reproduction, or *parthenogenesis*. The male germ cell never develops by itself; it must always be united with at least a part of an egg cell.

The female germ cell, then, being the one on which the responsibility of development depends, is usually protected in some way from destroying influences, either by being inclosed in a tough shell, or by being retained within the body of the mother during the early part of its developmental period. If the egg is extruded from the body of the parent and must develop after that without receiving any nourishment from the mother, there is provided within its shell an amount of nutrient material sufficient to carry it through to the time when the newly formed creature can leave the shell and obtain food for itself. This nutrient material within the egg is called *yolk*.

The eggs of insects have a great variety of shapes, determined by the shell (fig. 1). Some are round, some are oval, some are flat; some are smooth on the outside, some ridged or variously sculptured. Some are laid by the female in the most exposed places, others are deposited where they will be protected, as under bark, in the ground,

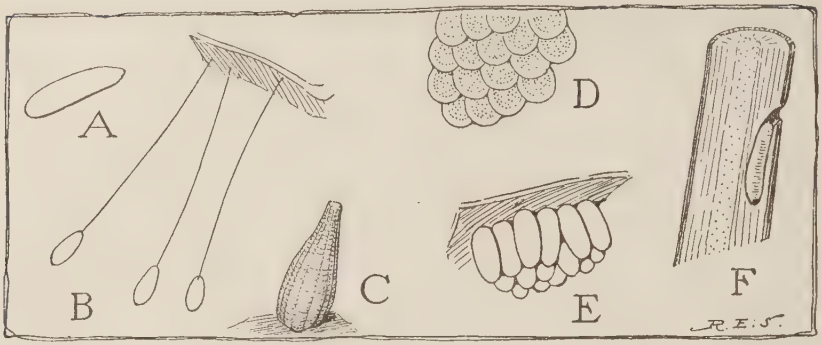

FIG. 1.—Various forms of insect eggs (all much enlarged, but not to same scale) A, egg of a housefly; B, stalked eggs of a lacewing fly, the golden-eye, attached to under surface of a leaf; C, egg of a cabbage butterfly; D, flat, overlapping eggs of a leaf-roller moth; E, eggs of potato beetle on under surface of a leaf; F, egg of the snowy tree-cricket inserted into an apple twig.

in the stems of plants, or in the bodies of other insects. Eggs such as the latter, including the eggs of grasshoppers, beetles, flies, are usually of a long-oval form, slightly curved, and a trifle smaller at one end than at the other. An egg of this kind will be the most convenient to take as a type for study (fig. 1, *F*, fig 2).

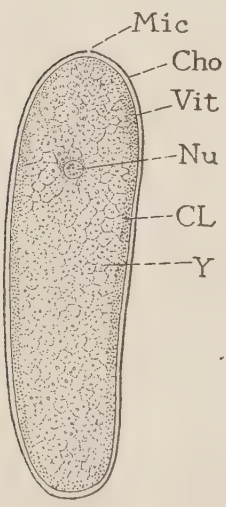

FIG. 2.—Section of a typical insect egg, showing its internal structure

Cho, chorion, or outer shell; *CL*, cortical layer of protoplasm; *Mic*, micropyle; *Nu*, Nucleus; *Vit*, vitelline membrane; *Y*, yolk.

The external covering of the insect egg is called the *chorion* (fig. 2, *Cho*). It is composed of a tough, flexible substance, quite unlike the brittle shell of a bird's egg, deposited upon the egg from the wall of the egg tube. The young insect when ready to hatch either splits the egg shell or gnaws a hole in it large enough to allow it to emerge. An example of the first method of emergence was given in the description of the hatching of a young cicada in the Smithsonian Report for 1919, page 407, and an example of the second method in the hatching of a young cankerworm described in the Smithsonian Report for 1924, page 334.

The newly laid egg appears to contain nothing but a clear, watery, or creamy liquid, but when examined under the microscope in specimens prepared and stained for microscopic study, the interior of the egg is seen to have a complex organization. Its fundamental substance is protoplasm, but most of its bulk consists of yolk materials (fig. 2, *Y*) that are mixed with the protoplasm. The protoplasm itself is visible principally as a thin layer at the surface of the egg (*CL*);

elsewhere it appears to be reduced to a mere network of strands in the yolk. Near the center of the egg, or usually nearer one end, in an island of protoplasm, is the *nucleus* (*Nu*), a small body, but one of great importance and of complicated structure. The soft parts of the egg are all contained in a delicate *vitelline membrane* (*Vit*), just within the chorion, which is a product of the egg itself.

The egg nucleus consists of a nucleus plasm separated from the surrounding egg plasm and yolk by a nuclear membrane. Within the plasm of the nucleus is a fine network upon which, during

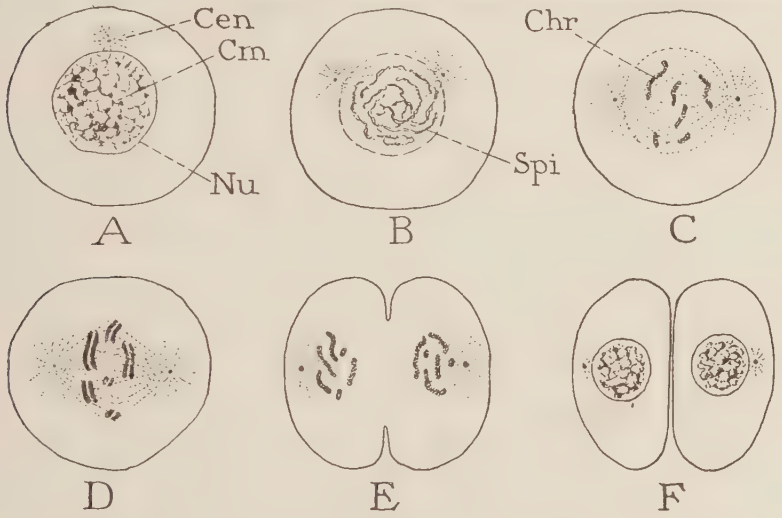

FIG. 3.—Diagram of cell division, involving special activities in the nucleus

A, cell in ordinary condition with chromatin (*Cm*) distributed through nucleus (*Nu*), and centrosome (*Cen*) undivided; B, cell preparing to divide, chromatin in spireme threads (*Spi*), centrosome divided and halves moving to opposite poles of nucleus, nuclear membrane disappearing; C, spireme threads condensed to chromosomes, centrosomes at opposite poles of nucleus with spindle between them, nuclear wall gone; D, chromosomes in plane between the centrosomes, each splitting into two; E, chromosomes divided and half of each drawn to opposite ends of nucleus, cell dividing; F, chromatin dispersed in two new nuclei, and cell completely divided.

ordinary periods of inactivity (fig. 3 A), are scatered many small grains of a dark-staining substance called *chromatin* (*Cm*).

The egg and the sperm are cells, and the most important activity of cells in general is that of division, a process by which a single cell becomes two cells; and upon this depends the power of growth and reproduction. The usual method of cell division involves interesting changes in the nucleus, and must be understood before we can proceed with the subject of development.

When a cell is preparing to divide, the chromatin granules of its nucleus arrange themselves in a number of long thread-like strands (fig. 3 B, *Spi*), or in a single strand that later breaks up into pieces.

In either case the threads contract and thicken till they form dark-staining bodies or masses of chromatin material. These bodies are the *chromosomes* (C, *Chr*). The number of chromosomes is in general constant for each species, there being in insect cells commonly between 2 and 30 of them, though in some species there is a much larger number. The chromosome number, however, is typically not the same in male and female cells of the same species, the male cells usually having one less chromosome than the female cells. But in some insects this rule is reversed, while in others the male cells have as many chromosomes as the female cells, though in such cases one is usually very small, as if in the process of being eliminated. The different chromosomes in each cell of many species, moreover, have characteristic individual shapes and sizes by which they can always be identified and distinguished from one another. In the diagrams, Figures 3 to 6, and 9, three varieties of chromosomes are represented, but these are conventional figures not intended to represent cells of any particular species, and the reader must not get the impression that chromosomes are necessarily of these forms.

The division of the cell starts with the nucleus, and, indeed, with the chromosomes themselves (fig. 3 D), each of these bodies splitting lengthwise into halves. Preceding this division of the chromosomes, however, a minute speck, called the centrosome (A, *Cen*) lying just outside the nucleus, has divided and its two parts have moved to opposite poles of the nucleus (B, C). The nuclear wall now disappears and fine colorless lines radiate through the nucleus from the two centrosomes, forming a spindle-shaped figure between them (C). The chromosomes (*Chr*) become arranged across the middle of the spindle (D) and then, as if pulled by a contraction of the threads, their separated halves move to opposite ends of the nucleus (E). Here they form two new nuclear groups, each of which becomes surrounded by a new nuclear membrane (F). At the same time, the cell itself constricts between the nuclei (E) and finally separates into two daughter cells (F), each of which increases in size and becomes in all respects a replica of the original cell. Growth in all animal and plant tissues takes place by cell division, and most cell divisions involve these complicated changes in the nucleus.

We have seen that the original germ cells of any species ordinarily contain the same number of chromosomes as the body cells of this species. What, then, happens when two of them come together in fertilization—is the number of chromosomes doubled? No; for in the course of a few generations the number of chromosomes would increase to impossible numbers. For a while, the germ cells multiply by divisions of the ordinary sort just described, resulting in

more cells like the original ones. But finally there comes a time when a new kind of division intervenes which, instead of preserving the original number of chromosomes, reduces it. The chromosome threads may appear in the ordinary manner and in the usual number, but they develop an attraction for one another which leads them to come together and unite in pairs (fig. 4 A, B, C). This mating of the chromosomes is called *synapsis* (from two Greek words meaning a union), and a most interesting thing about it is that it consists, not of a haphazard union of any chromosome with any other, but of a definite pairing of corresponding male and female chromosomes descended from the parent chromosomes that came together

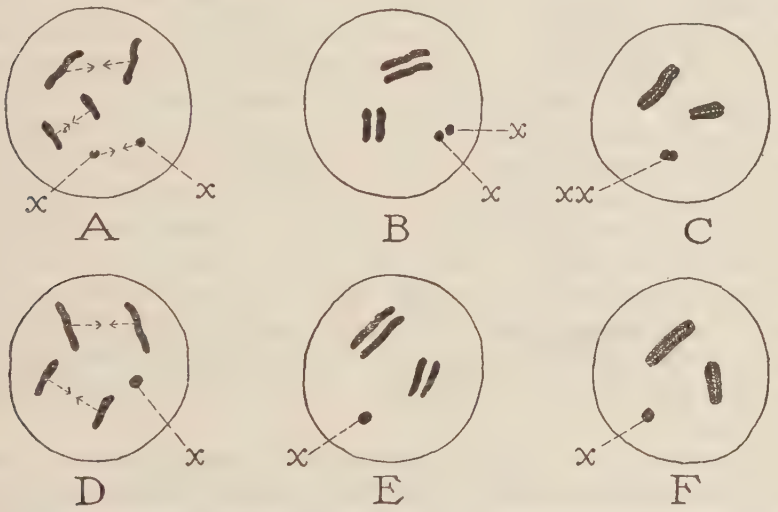

FIG. 4.—Diagram of synapsis, or the mating of the chromosomes prior to the maturation divisions

A–C, synapsis in a female germ cell nucleus with six chromosomes, including two x-chromosomes (*x*, *x*), resulting in a nucleus (C) with three double chromosomes, including one double x-chromosome; D–F, synapsis in a male germ cell nucleus with four orthochromosomes and one x-chromosome, resulting in a nucleus (F) with two double orthochromosomes, but with one single x-chromosome.

at the fertilization of the egg from which this generation of germ cells was derived. At least, there is very good evidence that this is what takes place; it is even suggested by some writers that there is an interchange of substance between the chromosomes while mated, thus bringing about a redistribution of hereditary characters carried by the chromosomes.

We have seen that the chromosomes are often distinguished by visible differences in size or shape. Two of the chromosomes in the female egg cell before synapsis are of special interest, for reasons that will appear later, and are usually referred to as the female

x-chromosomes, the others collectively being known as the autochromosomes, or *orthochromosomes*. One x-chromosome came from the female parent cell, the other from the male. At synapsis the two x-chromosomes pair with each other, producing one double x-chromosome. Thus, for example, if an egg cell contained originally six chromosomes in all (fig. 4 A), two of which were x-chromosomes (x, x), its chromosome formula after synapsis is $2+1x$ (fig. 4 C), but with each chromosome now of double value. With all egg cells having an even number of chromosomes, as we have seen most female cells have, the mating of the chromosomes in synapsis reduces the number of chromosomes to just one-half the original number. Chromosome reduction in the egg, therefore, is a simple matter of dividing by two in most cases. But what happens during synapsis to a male germ cell with an odd number of chromosomes? Simply the most natural thing: The corresponding orthochromosomes pair with each other; the x-chromosome, being without a mate, remains single (fig. 4 D, E, F). Hence, in a male cell with five original chromosomes, the chromosome formula after synapsis becomes $2+1x$, the same as in the egg cell of the same species, except that the x-chromosome is of single value. In male cells that have an even number of chromosomes, the x-chromosome has a small mate, which is designated the y-chromosome. After synapsis in one of these cells having $4+x+y$ chromosomes, the chromosome formula becomes $2+xy$, in which xy represents a single double chromosome.

After the chromosomes are paired off, the chromatin material may again become strung out in the form of threads, but in any case the threads soon take on the typical chromosome forms as in the stage preceding cell divisions, for there is now about to take place two special divisions of the germ cell which will prepare it for the eventual union with a germ cell of the opposite sex in fertilization. These two divisions of the germ cells constitute the process known as maturation. Synapsis, in nearly all cases in animals, precedes the first maturation division; in a few species of insects, however, it precedes the second division.

The insect egg up to the time of maturation has been still within one of the egg tubes of the parent female, where it has grown enormously by the accumulation of yolk in its protoplasm. In its early stages it divided entire, like any other cell, but now, on account of its bulk, it can no longer conveniently do so. Henceforth all its divisions will affect only the nucleus. At this stage the egg is usually laid, and maturation takes place immediately afterward. At the beginning of maturation the nucleus moves nearer the surface, and at the first maturation division the halves of each

chromosome pair, united in synapsis (fig. 5 A, *a*), are again separated on a division spindle and pass to opposite poles of the nucleus to form the two new nuclei. After this division, therefore, each new nucleus contains the same reduced number of chromosomes as before (fig. 5 A, *b*), but the chromosome material itself has undergone a redistribution between the new nuclei, since the individual chromosomes were not divided between them as in ordinary cell division. The separated halves of the paired chromosomes do not necessarily all go in the same direction, the male or female element in some going to the one pole and in some going to the

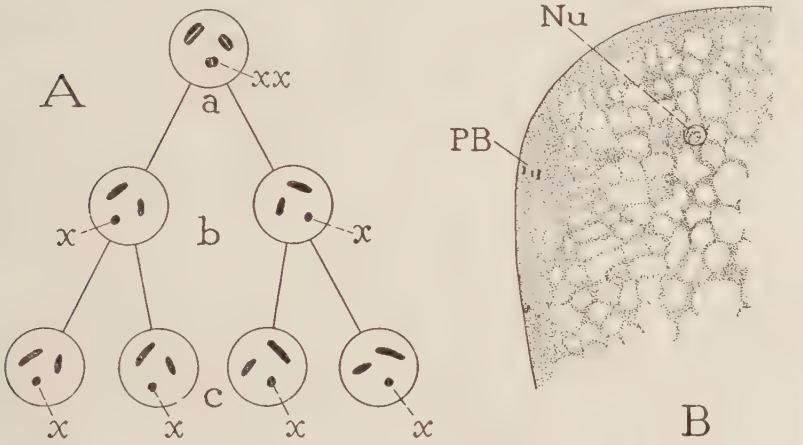

FIG. 5.—Maturation of an egg

A, diagram of chromosome division in maturation: each double chromosome in nucleus (*a*), after synapsis (fig. 4C), divides into single chromosomes of nuclei of first division (*b*); in second division, each single chromosome splits into two, resulting in four nuclei (*c*), each with same number of chromosomes, but with half the number contained in the original cell (fig. 4A). B, section of upper end of egg of a honeybee just after maturation, showing the three small polar body nuclei (*PB*), and the large functional egg nucleus (*Nu*) now ready for fertilization. (Figure from Petrunkevitch.)

other, so that whatever hereditary influences they may carry will be distributed by chance in all possible combinations. The second maturation division immediately follows the first, but in this division the original chromosomes divide lengthwise each into two as in ordinary division, thus producing four nuclei, two of which are replicas of one of the first-formed nuclei, and two of the other (fig. 5 A, *c*). The chromosome number, however, is the same in all, the formula being $2+1x$ for nuclei descended from one with six original chromosomes.

Figure 5 A represents diagrammatically only what takes place in the nucleus of the maturating egg cell; a truer picture of the results of the maturation divisions is shown at B. Three of the new nuclei

produced are very small, while one maintains the normal size. This large nucleus becomes the functional nucleus of the maturated egg (*Nu*); the three small ones, known as the *polar bodies* (*PB*), are rudimentary nuclei that move to the surface of the egg plasm where they degenerate and are absorbed in the yolk. Only in exceptional cases do the polar bodies play a special part in development.

The egg is now ready for fertilization. The nucleus sinks back again into the deeper part of the egg plasm and yolk, and the egg, unless it is one of those capable of parthenogenetic development, has no further history until a spermatozoön unites with its nucleus. In the course of normal events with most insect eggs, however, a spermatozoön has already entered the egg plasm, or more probably several have entered (fig. 8), so that one is almost certain to accomplish its purpose. Before going on with the subject of fertilization we must, then, learn something of what has happened to the sperm cells during maturation, how they have become transformed into spermatozoa, and how the spermatozoa gained an entrance into the egg.

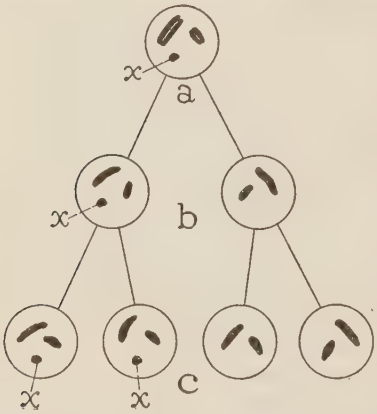

FIG. 6.—Diagram of chromosome division during maturation of a sperm nucleus (*a*) containing two double orthochromosomes and one single x-chromosome after synapsis (fig 4F). The first division produces two nuclei (*b*), of which one contains two single orthochromosomes and one x-chromosome, and the other only two orthochromosomes. The second division produces four nuclei (*c*), two with an x-chromosome, and two without an x-chromosome.

The original male germ cells ordinarily contain the same number of chromosomes as the body cells of the male insect that bears them, but male cells in general, as we have seen, differ from female cells of the same species by having only one x-chromosome in the nucleus, or in having a small y-chromosome as a mate for the x-chromosome. The male of a species in which the female germ cells have six chromosomes would most likely have five chromosomes in the nuclei of its germ cells (fig. 4, D), which would mean a chromosome formula of $4+1x$. The single x-chromosome, having no mate, remains single after synapsis (fig. 4 F), when the chromosome formula of the male becomes $2+1x$. At the first maturation division (fig. 6, *a*), therefore, the x-chromosome can not divide, and it has to choose between going with one group or the other of the orthochromosomes. As a consequence, one of the new nuclei will contain an x-chromosome, and the other will not. Two kinds of

sperm cells are thus differentiated, one having the usual chromosome formula of $2+1x$, the other having simply two orthochromosomes (fig. 6, *b*). At the second maturation division, when all the chromosomes divide in the usual manner, four cells are formed, two of which are of the $1x$ variety, and two of the no-x variety (fig. 6, *c*). In cases where a y-chromosome is present with the x-chromosome, there are still two classes of sperm cells produced, one having the x-chromosome, and the other the y-chromosome, since these chromosomes are separated in the first division after their union in synapsis.

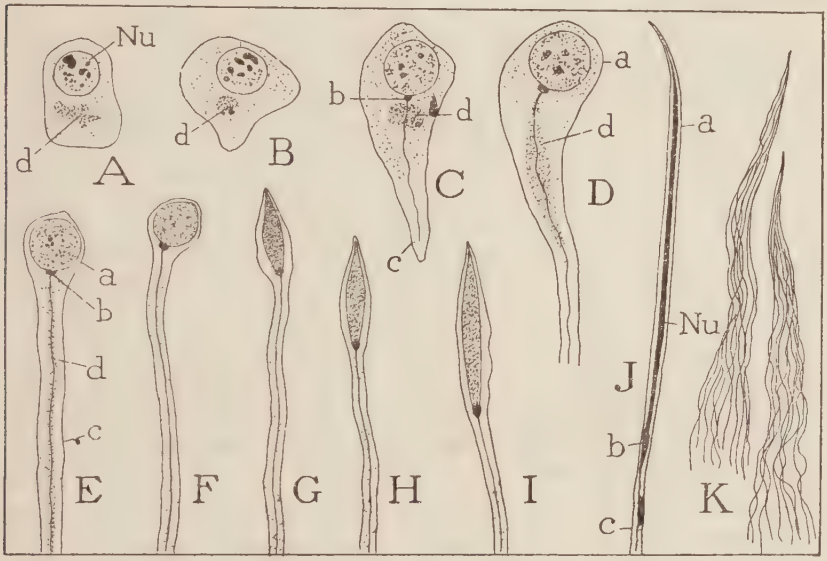

FIG. 7.—Spermiogenesis, or the transformation of the male germ cell after maturation into a spermatozoön, and the mature spermatozoön

A–J, spermiogenesis in a grasshopper (figures from H. S. Davis): *a*, head of the spermatozoön; *b*, the middle piece, from which a long filament extends out into the tail; *c*, the tail, formed by elongation of the cell body (B, C, D); *d*, a body in the cell (A, B) that eventually surrounds the tail filament (D, E); *Nu*, the nucleus, which remains in the head (J). K, bundles of spermatozoa from the spermatheca of a female broad-winged katydid.

The divisions of the male germ cells always affect the entire cell, since the male cells do not accumulate yolk, and remain small. Furthermore, the maturation of the male cells, with few exceptions, produces four equal-sized cells, all of which ordinarily will become functional spermatozoa. At this stage each sperm cell, now known as a *spermatid*, still has the rounded or oval form of an ordinary cell. To become a fully-formed spermatozoön it must undergo a metamorphosis, a process too complicated to be described here in detail, but which results in a transformation of the simple spermatid into a thread-like spermatozoön (fig. 7). The mature spermatozoön, how-

ever, is not a simple filament; under a high-power microscope there can be distinguished in it a number of parts: First, there is a head (fig. 7, D, E, J, *a*) containing the nucleus (*Nu*), then comes a short body or middle piece (*b*), and finally a long, tapering tail (*c*). The tail acquires the power of movement and can be lashed sideways with a wavy motion, which lashing drives the sperm forward with much speed when the sperm is immersed in a liquid. The male germ cell has now become virtually a minute one-celled animal, and has arrived at the stage in which it is capable of fertilizing a maturated egg cell.

All the processes thus far described concerning synapsis and maturation of the germ cells, and the transformation of the spermatids into spermatozoa apply to animals in general, including man, and it must not be supposed they are limited to insects. The processes have been extensively studied in insects because they are more easily seen in many insect germ cells than in the cells of higher animals. The same is true of fertilization, a description of which will soon follow, but many of the accessory processes as they occur in insects are peculiar to insects. During mating, for example, the spermatozoa from the male insect are stored in a special sac within the body of the female. This sac, known as the spermatheca, is connected with the outlet duct of the female's ovaries. The eggs may not be deposited for some time after mating, the time varying with different species, sometimes a few hours, sometimes a few days, or a considerable length of time may elapse. With the honeybee the spermatozoa are capable of remaining alive and functional in the queen for three or four years.

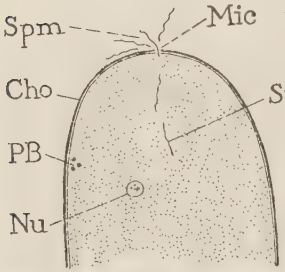

FIG. 8.—Diagram representing the entrance of spermatozoa (*Spm*) into the egg through the micropyle (*Mic*). *Cho*, chorion; *Nu*, egg nucleus after maturation; *PB*, polar bodies

Whenever an egg is laid a number of spermatozoa in a spermatic liquid are discharged from the sperm sac upon the upper end of the egg as the latter goes by the mouth of the sperm sac. Some of these spermatozoa almost invariably find their way into the egg through a minute aperture in the shell, the micropyle (fig. 2, *Mic*), penetrating the vitelline membrane and entering the egg plasm by the force of their own motion (fig. 8). The first of these spermatozoa to reach the egg nucleus is the one that mates with it; the unsuccessful perish in the egg and are probably absorbed in the yolk.

FERTILIZATION

Once the spermatozoön is within the plasm of the egg it travels inward, at first straight away from the point of entrance, though such a course is not necessarily toward the egg nucleus. The latter, as we have seen, is moving at the same time deeper into the egg from the place where it gave off the polar bodies. The sperm soon alters its course to one that will intersect the path of the egg nucleus. The two bodies then eventually meet as if mutually drawn to the same point in the egg plasm, but the influences that effect the meeting are entirely unknown, as are also the forces that bring about the subsequent activities of fertilization. Consequently we may confine ourselves to a narration of the facts as they occur, which are interesting enough in themselves, without bothering for the present with speculations as to what causes them. When the sperm and the egg nucleus meet, the sperm casts off its body and tail into the egg plasm while its nucleated head fuses with the egg nucleus. The substance of the two nuclei then becomes inclosed in a common membrane, thus establishing a new nucleus, in which the original chromosome number is restored, since this nucleus now contains the sum of the female and the male chromosomes.

The union of the male and female germ cells is the visible phenomenon of fertilization, but it brings about such remarkable results in the egg as to show that there are most important processes involved not yet revealed under the microscope. Fertilization accomplishes at least three things: First, it stimulates the egg to begin development; second, it adds to the egg a new set of hereditary characters or influences derived from the male line of descent; and third, it apparently determines in the egg of most animals the sex of the future individual.

The nature of the stimulus given to the egg by the sperm is not certainly known, but that it is a chemical one is indicated by the fact that some eggs can be stimulated to begin development by being artifically treated with certain substances. Perhaps, on the other hand, the effect is due to the destroying of some inhibiting influence, since insect eggs that develop without fertilization clearly demonstrate that the sperm element is not necessary to them. The hereditary influences brought together by the two conjugating cells constitute a subject too large to be discussed here; the facts associated with the establishment of sex in the ensuing individual, however, are too interesting to be passed over.

It is clear that the number of chromosomes in the fertilized egg nucleus will depend on the number in the particular spermatozoön

that fertilized it. If the sperm was one of those having the same number of chromosomes as the egg—i. e., one with an x-chromosome—the new nucleus will have just twice the number of chromosomes that was in the maturated egg nucleus, and, therefore, the same number as that of the original female germ cells and the female body cells of its species. The resulting individual will consequently be a female. If, on the other hand, the fertilizing sperm happened to be one of those with no x-chromosome, the number of chromosomes in the new nucleus will be one less, and will be the same as that in the original male germ cells and in the male body cells. The new individual will be a male. To illustrate with our hypothetical example used before: If a maturated egg nucleus containing $2+1x$ chromosomes (fig. 9 A, b) is fertilized by a sperm nucleus (a) with $2+1x$ chromosomes, the new nucleus (c) will have $4+2x$ chromosomes, the female formula; but if the same egg, or another like it (B, e), should be fertilized by a sperm (d) having only two ordinary chromosomes, the new nucleus (f) will have $4+1x$ chromosomes, the male formula for the same species. Sperms containing y-chromosomes give the same result, differentiating the eggs by the chromosome formulas of $4+2x$ and $4+$xy. Therefore, apparently according to the presence of two x-chromosomes or of only one, the number resulting by "chance" in the fertilization of the egg, the new individual developed from the egg will be either female or male.

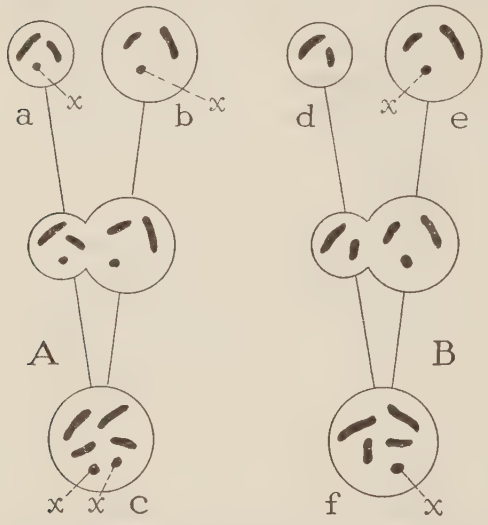

FIG. 9.—Diagram showing results of fertilization of eggs by the two kinds of sperm (fig. c)

A, a maturated egg nucleus (b) containing two orthochromosomes and one x-chromosome, fertilized by a spermatozoön (a) having the same number of chromosomes, producing a fertilized egg nucleus (c) with four orthochromosomes and two x-chromosomes, which now contains the original female assortment of chromosomes (fig. 4A). B, a maturated egg nucleus (e) of the same species fertilized by a sperm (d) containing only two orthochromosomes, producing a fertilized egg nucleus (f) with four orthochromosomes and only one x-chromosome, which is the original male assortment of chromosomes (fig. 4D).

The reader must understand, now, that in spite of appearances, it is not certain that sex is actually determined by the x-chromosomes, or by any of the chromosomes. Though in the great majority of animals the number of x-chromosomes appears to be

the deciding thing, it may be that the real determining influence is something that escapes the scrutiny of the microscopist, and that the chromosome combination is merely coincident with it. This doubt is raised by the fact that in some plants and in some of the lower animals, sex is not necessarily fixed at the time of fertilization, and may either be established later or influenced by external circumstances. It is certain, however, that with the great majority of animals of all kinds sex is determined at the time of fertilization and that nothing can change it subsequently.

Certain other characters that will appear in the new individual as a part of its inheritance, besides those of sex, are known to be linked with the chromosomes, but these are mostly traits that characterize individual lines of descent, or varieties within the species. The determining factors of the inheritance of fundamental species characters by individuals of both sexes are supposed to be contained in the bodies of the germ cells themselves.

DEVELOPMENT

Growth and development are not the same thing, but they are so closely associated in animals that usually the animal continues to develop as long as it grows, and grows only during its developmental period.

Growth takes place through a repeated division of the egg cell or of a part of it to form a mass of cells that continue to multiply by similar divisions. Development consists of a gradual, definite arrangement in the growing mass of cells to form the various parts and organs of the future adult—a new individual having all the structural details characteristic of the species to which it belongs, as well as some or all of the peculiarities of its parents and immediate ancestors, but having also, in most cases, minor characters of its own. Thus, heredity keeps each new individual close to the ancestral path and maintains the line of descent; but the freedom of each individual to deviate slightly from the ancestral path has made evolution possible, and has resulted in the vast number of species of animals and plants in the world to-day.

THE BEGINNING OF DEVELOPMENT

With those species of animals whose eggs contain only a small amount of yolk, development starts with the division of the entire egg into two cells. A few insect eggs develop by entire division, but most of them are so enlarged with yolk, like a bird's egg, that it is only the neucleus and a small amount of the surrounding

protoplasm that divides, the rest of the egg remaining intact (fig. 10 A). As the newly formed nuclei redivide, the resulting nuclei scatter through the yolk (B) and migrate outward in all directions until they come into the protoplasmic layer at the surface. Here they eventually become evenly arranged in a single layer (C), and then the containing protoplasm condenses about each nucleus (D), resulting in a layer of small nucleated cells enveloping the yolk (E). This cell layer, having now the form of the egg, is the *blastoderm* (D, E, *Bl*). Eggs that divide by the entire method arrive at the blastoderm stage simply by multiplying until they form a hollow ball of cells. This is a simpler procedure, but one that is practicable only with eggs that are not heavily loaded with yolk.

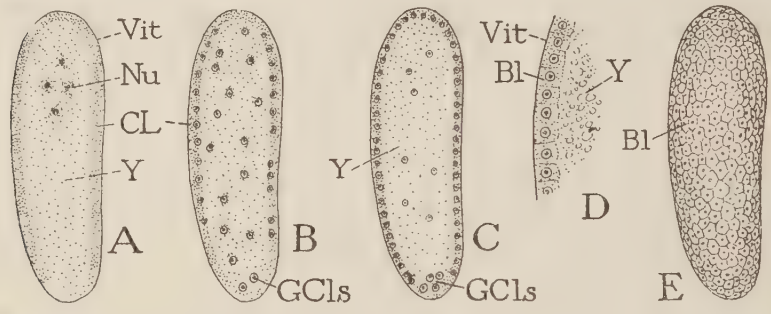

FIG. 10.—Formation of the blastoderm

A, development begins with the division of the egg nucleus into several cleavage nuclei (*Nu*) within the yolk (*Y*). B, the multiplying nuclei migrate outward into the cortical layer of protoplasm (*CL*); several at the posterior pole of the egg become the germ cells (*GCls*). C, the nuclei in the cortical protoplasm soon form a definite layer at the surface of the egg; a few nuclei remain in the yolk; the germ cells increase in number. D, the cortical protoplasm condenses about each surface nucleus to form a layer of cells, the blastoderm (*Bl*), surrounding the yolk beneath the vitelline membrane (*Vit*). E, the blastoderm in surface view.

FORMATION OF THE GERM CELLS

The cells of the blastoderm are in general all alike, but in many insects a group of cells appears at the posterior end of the egg (fig. 10 B, C, *GCls*) at the time the blastoderm is forming which remain distinct from the true blastoderm cells. These cells likewise are immediate descendents of the egg nucleus, but their destiny is quite different from that of the other cells—they are the primitive germ cells of the future individual whose body is to be formed by the blastoderm cells. Here we have, then, differentiated at this early stage, two sets of cells, one of which will form the body cells of the generation now developing, while the other will form the body cells and the germ cells of the succeeding generation. This relation is easily seen in the diagram, Fig-

ure 11, in which for convenience the products of only one germ cell are shown for each generation. As the new individual develops, the germ cells wander among the body cells for a while, but at last they become lodged in the reproductive organs (figs. 24, 27, *GCls*). Here they multiply in number and undergo their development into the mature eggs or spermatozoa, according to the sex.

The mass of body cells, consequently, appears to be but a mere side issue from the germ cells, a specialized group of nonreproductive cells that the germ cells have produced for their own protection. It is most probable that in the evolution of animals all the cells were originally alike, and that the division of labor between them has had the usual consequence; the germ cells, in leaving the vegetative functions to the body cells, have lost most of their capacity for functions other than that of reproduction; while the body cells, in specializing on the vegetative functions, have lost the reproductive function. The one-celled animals, however, having

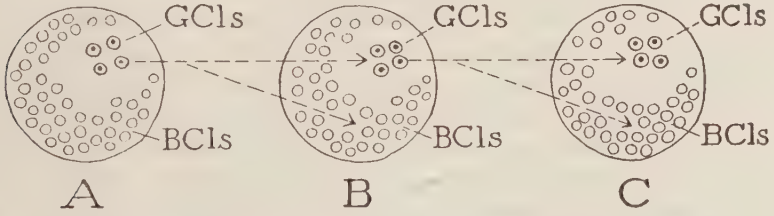

FIG. 11.—Diagram showing relation of germ cells (*GCls*) and body cells (*BCls*) in successive generations. A germ cell of A forms the germ cells and body cells of B; a germ cell of B forms the germ cells and body cells of C, etc. The offspring (C) of B derives nothing from the body cells of the parent (B), but both offspring (C) and parent (B) have a common origin in a germ cell of A, the grandparent of C

never differentiated into the two sets of cells, retain in themselves all the normal functions of a cell. But, in some of the lower many-celled animals, the body cells also have not entirely lost the power of reproduction, since in some species a body cell or a group of them detached from the body may multiply and reproduce a new body. The first-formed body cells of the developing egg, too, are reproductive cells in this sense, since it is they that carry on the constructive work delegated to them by the parent germ cell; and all the body cells, in retaining the power of division, retain the power of reproduction. All such forms of reproduction, however, are of the asexual type; the distinctive quality of the true germ cells is their ability to unite in fertilization and produce a new individual combining the qualities of two others, though this is not always a necessary condition with the egg cell.

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During the period of the first divisions in the developing insect egg, there is no evidence to show that any cell may not become either a body cell or a germ cell, or that any particular body cell has from the beginning a special destiny. When the body cells later become organized into layers and groups, they become more and more restricted in their reproductive powers, each group forming only certain organs and tissues of the future animal. In the adult stage even this power is largely lost in the cells of higher animals, which can now multiply only to the extent of healing wounds. Lower in the scale of organization, however, lost members of the body can be regenerated from a stump, or even the greater part of the body may be re-formed from a fragment. At last, though, there comes a time when the vitality of the body cells is lost, or is completely suppressed, and the animal dies.

Though the body cells are by nature merely the servants of the germ cells, we look upon the structure that they form as the reason for the existence of the germ cells, because it is the visible, sentient animal in which are developed all the powers of reaction to external stimuli, the instincts, self-consciousness, and intelligence that is potential in the germ cell. But these faculties are all developed for the purpose of maintaining the germ cells, for bringing them together, for nourishing, protecting, and educating the offspring. No creature, therefore, according to the plan of nature, lives for itself; its whole reason for existence is the next generation. This does not mean, however, that every individual of a species should be a reproductive individual. Among the social insects, the ants and bees, for example, certain individuals are designed to be accessory to the reproductive individuals. These are the so-called workers and soldiers that build the nest or comb, protect the community from invasion, attend to the collecting and storing of food, rear and feed the young—members of the community which, in short, are indispensible to it through their services to the reproducing castes and to the offspring of the latter.

Since the germ cells and the body cells of each individual are produced side by side, and not one from the other, heredity, as a consequence, is not directly from one generation to the next, but between alternate generations. In figure 11 it is seen that the germ cells and the body cells of generation C, for example, find their common ancestor not in the parent generation B, but in a germ cell derived from the grandparent generation A, which cell is contained and developed in B. The common resemblance between parent and offspring, then, is due to the developmental influences embodied in the germ cells, which produce similar results in the body cells of successive generations, and not to influences exerted by the body cells on the germ

cells. It is fortunate that the body cells do not impress their characters on the germ cells, else the offspring would inherit all the malformations of the parents and all the results of accidents, amputations, and diseases that may befall the parents.

Enough has now been said of the germ cells, since we have traced both their origin and their final development into mature reproductive cells. Something might be said of the intervening part of their history in the reproductive organs of the parent individuals, showing how they are here multiplied and nourished, but this would take too much time from our main theme, which from here on will be concerned only with the history of the body cells, or the development of the young insect from the blastoderm.

THE GERM BAND

In the blastoderm stage (fig. 10 C, E), the developing insect consists of a mere cellular sac (*Bl*) inclosing the yolk (*Y*) and a

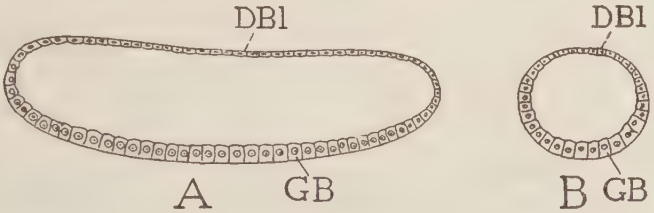

FIG. 12.—The formation of the germ band (*GB*) as a thickening of the cells of the ventral side of the blastoderm, the cells of the dorsal side, or dorsal blastoderm (*DBl*), remaining thin. A, lengthwise section of egg. B, cross-section.

few nuclei left behind in the latter, and is surrounded by the vitelline egg membrane (D, *Vit*) and the chorion (fig. 2, *Cho*).

The next thing that happens in development consists simply of a thickening of the cells in a band along what is generally the more convex side of an elongate-oval egg (fig. 12 A). This surface is called the ventral side of the egg, because it is to be the under surface of the fully formed insect. The ventral thickening of the blastoderm is known as the *germ band* (*GB*). It must be explained here that the word "germ," unfortunately, will appear in many embryological terms, but without implying that the parts so named have anything to do with the germ cells. The use of the word "germ" in two senses was started long ago when distinctions were less finely drawn than now, and more exact terms have not yet come into general usage. The germ band may be regarded as the beginning of the embryo; its edges grade off into the thin blastoderm cells still covering the rest of the egg, and known as the dorsal blastoderm (fig. 12 A, B, *DBl*).

THE GERM LAYERS

Soon after the germ band is formed, its middle part begins to sink inward, and may become separated from the part to either side by a slight ridge. The germ band thus becomes divided into two lateral plates (fig. 13 A, *LP*, *LP*) and a middle plate (*MP*). The middle plate is destined to form the strictly internal organs of the future insect, and it continues to sink inward, in some cases forming a deep median groove (B), which is then converted into

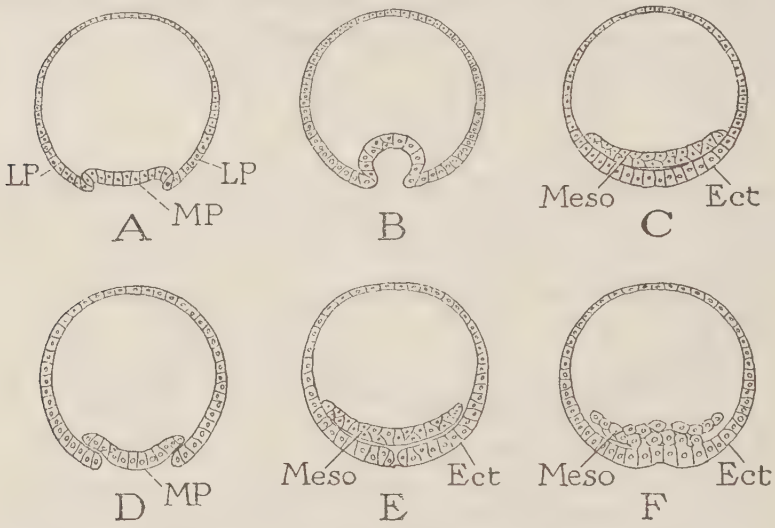

FIG. 13.—Showing diagrammatically three methods of formation of mesoderm layer in insects

A, cross-section of egg with germ band differentiated into lateral plates (*LP*, *LP*) and middle plate (*MP*). B, later stage of same with middle plate curved in to form a tubular groove, edges of lateral plates coming together below it. C, still later stage, with edges of lateral plates united, forming the ectoderm (*Ect*), and middle plate spread out above the latter as internal layer of cells, the mesoderm (*Meso*). D, E, second method of mesoderm formation: middle plate, separated from edges of lateral plates, becomes mesoderm (*Meso*) when lateral plates unite beneath it. F, third method, in which mesoderm (*Meso*) is formed of cells given off from inner ends of middle plate cells.

a sunken tube by the approach and union of the edges of the lateral plates beneath it. Finally, this middle plate forms a solid mass of cells which flattens out into a ventral layer (C, *Meso*) between the yolk and the outer layer (*Ect*) which is now continuous beneath it. The process of the formation of the inner germ layer differs somewhat from the above type in certain other insects. In some, for example, the edges of the lateral plates separate from the middle plate (fig. 13 D) and then grow together beneath it (E), the middle plate being thus cut off from the lateral plates and, by a more direct course, converted into the inner germ layer.

In still other species, the cells along the middle part of the germ band, which part may be slightly grooved (F), multiply by horizontal division and give off cells from their inner ends which constitute the inner layer (F, *Meso*). The first method of forming the inner layer is probably to be regarded as the typical one, and the others as modifications; it is to be noted that the modifications, as is usually the case in developmental processes, are but short-cuts to the same end as that attained more laboriously by the ordinary method of procedure.

By one or another of these methods the insect embryo comes to be changed from a one-layered to a two-layered condition. In this it follows the rule of all other animal embryos, though all do not arrive at the two-layered stage in the same way. Those embryos that consist of a hollow ball of cells in the blastoderm stage become two-layered simply by an infolding of one wall until they have the form of a double-walled cup. This method is regarded as typical of animals in general, and such processes as those that occur in insects are presumed to be derived from it in some way. With most embryos, furthermore, the next step consists in the formation of a third layer, derived from the second, which comes to lie between the other two. The three embryonic layers are then known as the *ectoderm* (the outer layer), the *mesoderm* (the middle layer), and the *endoderm* (the inner layer). These cell layers constitute three separate sets of embryonic building material, each of which will develop into specific tissues of the adult, and no one of which will normally substitute for another. The ectoderm, for example, always forms the outermost covering of the body and all parts derived from it; the endoderm forms the alimentary canal, or the essential parts of it; and the mesoderm forms the tissues between, including those of the muscles, the fat, the heart, the internal reproductive organs. Organs and systems of organs, however, often result from a combination of tissues produced by two or by all three of the embryonic layers. In descriptions, therefore, it is better to follow the development of organs rather than to trace separately the tissues that are produced from each embryonic layer.

Insect embryos do not closely observe the general rule for the formation of the embryonic layers. In the two-layered stage, the outer layer is the ectoderm (fig. 13 C, E, F, *Ect*), but the inner layer, as its subsequent history shows, is mostly the mesoderm (*Meso*). The endodermal tissues arise from ingrowths at the two ends of the mesoderm, as will later be described in tracing the formation of the alimentary canal.

Development proceeds by different rates of growth in the different parts of the germ band and the tissues resulting from it, shapes being attained by gradual infoldings or outfoldings, with

here and there a separation of one part from another. The processes of development might be imitated with a piece of soft clay or modeling wax, manipulated without adding anything and without taking anything away, pushing it in there, pulling it out here, until the form of the new creature is at last produced. The insect embryo ordinarily does not grow in size, except as it utilizes the yolk and replaces the latter with its own tissues.

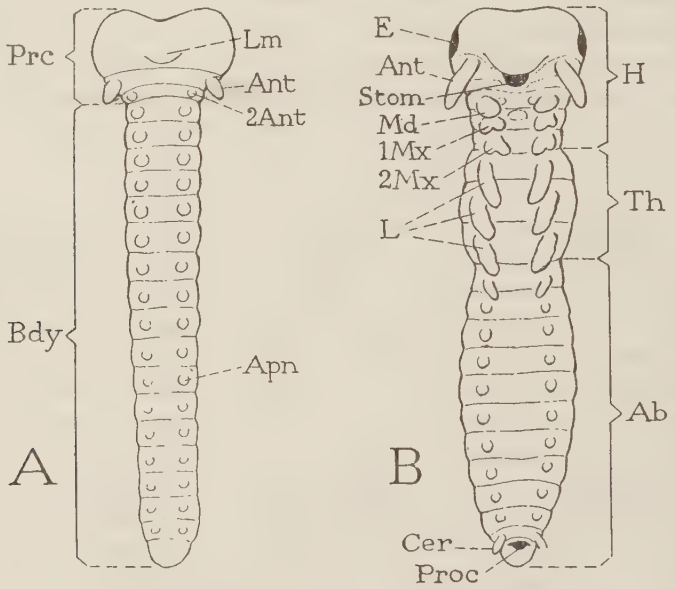

FIG. 14.—Two stages of the insect embryo, drawn diagrammatically, probably representing two periods in the evolutionary history of insects

A, early embryo consisting of embryonic head, or procephalon (*Prc*), formed of three segments, and of a body (*Bdy*) with as many as 18 segments, each but the last with a pair of ventral appendages (*Apn*). B, a later stage, showing segment grouping of adult insect; head (*H*) of six segments; thorax (*Th*) of three segments; abdomen (*AB*) of at most twelve segments.

Ab, abdomen; *Ant*, antenna; *2Ant*, rudimentary second antenna; *Bdy*, body; *Cer*, cercus; *E*, compound eye; *H*, head, of adult composition; *L*, legs; *Lm*, labrum; *Md*, mandible; *1Mx*, first maxilla; *2Mx*, second maxilla; *Prc*, primitive embryonic head, or procephalon; *Proc*, opening of protodeum (the anus); *Stom*, opening of stomodeum (the mouth); *Th*, thorax.

SEGMENTATION

Very early in the development of the insect embryo the two-layered germ band becomes marked by crosswise impressions, the lines appearing near the anterior end first and increasing in number backward. The continuous germ band thus becomes divided into a series of segments separated from one another by thinner inter-

segmental lines. There are never more than 21 segments formed in all; the number is usually fewer, and it is possible that the last division is not to be regarded as a true segment. Segmentation of the body is one of the fundamental characters of insects, but it is characteristic also of one large group of worms, of the crabs, lobsters, and shrimps and all their relations, of the centipedes, and of the spiders, as well as of other less familiar animals related to these several groups. Evolutionists take this to mean that all these creatures have had a common ancestry, and that the primitive ancestral forms were something similar to the segmented worms, since the latter are the simplest representatives of segmented animals living to-day. The segmented worms belong to the zoölogical group known as the Annelida, of which the common earthworm is a member; the other segmented animals mentioned above constitute the Arthropoda, of which the insects form one class, the spiders another, the centipedes another, and the shrimps, lobsters, crabs, and their relations another called the Crustacea.

In the insect embryo, the first three segments are usually but indistinctly marked, since they unite at an early stage to form a large bilobed swelling at the front end of the body (fig. 14 A, *Prc*). This swelling is the first embryonic head, named the procephalon ("kephalé" being Greek for head), and the embryo at this stage most likely represents an early ancestral stage in the evolution of insects, when an insect consisted of a three-segmented head and a long segmented body. As the embryo develops, however, it adds the first three primitive body segments to the procephalon and comes to have a head formed of six segments (fig. 14 B, *II*). This is the structure of the head of a modern adult insect, in which, though it eventually becomes a solid cranium-like piece, there is always to be discovered traces of a six-segment origin. The next three body segments become grouped to form the middle division, or thorax (fig. 14 B, *Th*), of the adult insect. The remaining segments constitute the abdomen (*Ab*), the number of segments in which varies in the adult in different insects, since some of the terminal ones may be lost during development, or have been lost in the course of evolution.

It is clear that insects in their evolution have tended toward a grouping of their segments to form a three-part body, and this body division becomes most accentuated in the higher members of the class (compare fig. 21, a grasshopper, with figure 15 D, a fly). Now, the members of the other classes of the Arthropoda have followed other lines of specialization in the grouping of the body segments and in the uses to which they are put. The crustaceans have aimed at a two-part division of the body, with the principal viscera in the first, and the second specialized as a swimming organ,

and the crustaceans have attained a high degree of development along this line. The spiders likewise have evolved a two-piece body (fig. 15 B), but with this difference from the crustaceans, that the principal viscera are contained in the second body division. The centipedes (C), on the other hand, have progressed but little farther than the acquisition of a six-segment head similar to that of the insects, the rest of the body being composed of a series of segments all pretty much alike. The insects (D) are characterized by having a head well separated by a neck from the thorax, by the

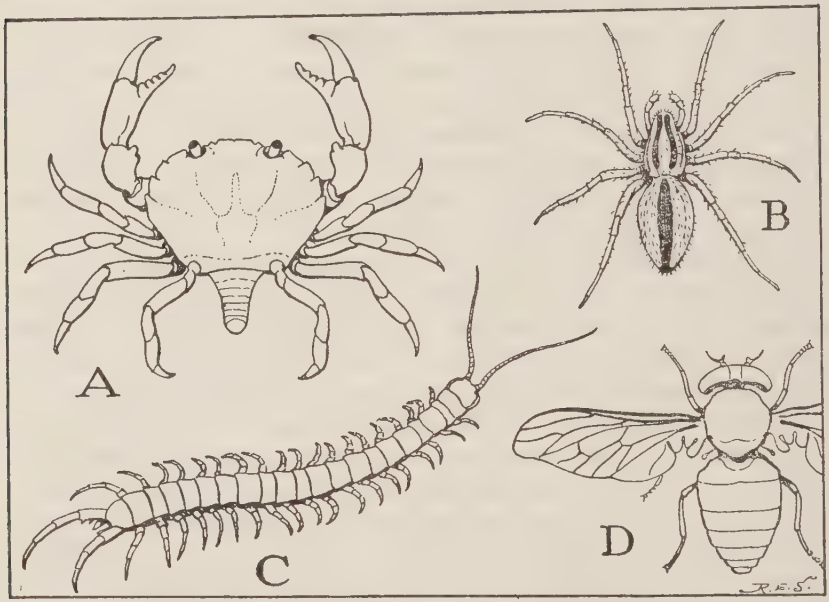

FIG. 15.—Principal types of animals evolved in the phylum Arthropoda by different groupings of the segments

A, a crab (Crustacea) with a two-piece body, no distinct head, the principal viscera in the first body division. B, a spider (Arachnida), also with a two-piece body and no distinct head, but with principal viscera in second part. C, a centipede (Myriapoda), with a head, and undivided body of many segments. D, an insect (Hexapoda), composed of head, thorax, and abdomen, with principal viscera in the last.

specialization of the thorax as the locomotory part, since it carries the legs and the wings, and by the development of the abdomen as a container for the larger viscera.

THE PRIMITIVE APPENDAGES

Closely connected with the evolution of the segments, in both insects and other arthropods, is the development of the external organs attached to them. One of the most conspicuous features of nearly all members of the Arthropoda is the number of legs or leg-like structures they have—"crawly" things these creatures are to most people on this account. Insects, it is true, have only three

pairs of legs (fig. 29, *L*), but on the head there is a pair of long antennæ (*Ant*) arising from the face, and other paired organs attached about the mouth (*Md*, *Mx*, *Lb*), while on the abdomen there is commonly an ovipositor, or egg layer, composed of two or three pairs of blades (*Ovp*), and near the tip a pair of slender cerci (*Cer*). All these members arising from the ventral parts of the several body regions are known collectively as the appendages. The wings (*W*) are not appendages in the technical sense, since they arise from the back and are not of the same nature as the antennæ, mouth parts, legs, and cerci.

The appendages appear on the embryo soon after the segments are distinguishable, and are at first mere swellings of the germ band, forming a row of buds on each side along the lines that will later be the edges of the under surface of the insect. The first and the last segments never acquire appendages, but the other segments, the second to the twentieth, inclusive, may have each a pair. Hence, though few embryos have the entire possible number of appendages, a "generalized" embryo would have the structure shown at B of figure 14, and this may be taken as the primitive embryonic structure, and probably as the ancestral one. In most insect embryos the abdominal appendages are but weakly developed, or are not formed at all at this stage, those that are present on the adult being developed at some stage after hatching.

To follow the development of the simple embryonic appendages into the various adult organs they become would be most interesting, but it would involve a long dicussion, and the following brief statements are all that can be given here. The first pair of appendages, those of the second segment (fig. 14 A, *Ant*), simply elongate into the antennæ of the mature insect and move forward from their original lateral position to one usually near the middle of the face. The appendages of the third segment, often called the second antennæ (*2Ant*), are at best but rudimentary organs in insects and disappear as the embryo develops (B), except in one species in which they are said to persist as small lobes in the adult. The appendages of the next three segments, the segments which are added to the primitive head (A, *Prc*) to form the head of the adult (B, *H*), become the feeding organs, or mouth parts, of the adult. These are the mandibles (B, *Md*), the first maxillæ (*1Mx*), and the second maxillæ (*2Mx*), the last uniting with each other to form the liplike labium of the adult (fig. 29, *Lb*). The appendages of the thoracic segments develop into the three pairs of legs (fig. 14 B, *L*). The abdominal appendages form various structures of the adult. In most insects those of the first seven segments disappear; parts of those of the eighth and ninth segments form the blades of the ovipositor (fig. 29, *Ovp*); and those of the eleventh segment (or perhaps of

the tenth) become the cerci (*Cer*), when these organs are present. In some of the lower forms of insects there are rudimentary appendages in the adult stage on some of the first seven segments of

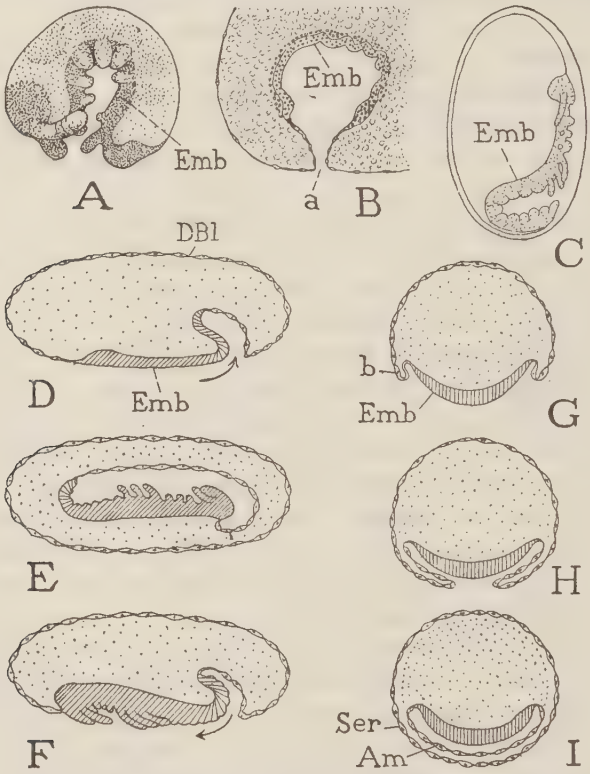

FIG. 16.—Three methods by which the insect embryo becomes protected within the egg

A, embryo (*Emb*) of a springtail (*Isotoma cinerea*) curved into the yolk on under side of egg. (Figure from Philiptschenko.)

B, C, embryo of Lepisma (a fish moth): first (B), at early stage when deeply sunken into yolk near posterior end of egg, the opening of the cavity closed to a small pore (*a*); and second (*C*), in later stage when partially revolved to outside of egg, in which position it completes its development. (Figures from Heymons.)

D–F, diagrammatic lengthwise sections of an egg in which the embryo revolves rear end first into the yolk (D), becoming entirely shut in the latter (E) in reversed and inverted position, and then again revolves to surface (F) in original position before hatching.

G–I, diagrammatic cross-sections of an egg in which embryo becomes covered by membranes originating in folds of the blastoderm around its edges (G, *b*), the folds extending beneath the embryo (H), and finally uniting to form two membranes (I), the outer the serosa (*Ser*), the inner the amnion (*Am*).

the abdomen, and the caterpillars have tubular legs on this part of the body (fig. 28), which are perhaps true abdominal appendages of a primitive structure.

From all the evidence bearing on the segments and the appendages, we may conclude, then, that the ancestral insects were creatures somewhat like centipedes, consisting of a series of segments having each a pair of appendages, and that modern insects have evolved from this simple form to their present complex structure by a definite grouping of their segments and a specialization of certain appendages, accompanied by a loss of those appendages that were found to be useless. This is not to say that insects are descended from centipedes. The centipedes have had their own line of descent from ancestors, which, perhaps, were the same as those of the insects. The insects have departed farther from the primitive type than have the centipedes.

THE EMBRYONIC COVERINGS

The embryos of most insects become protected in one way or another from the egg shell during a part or all of their period of development. With some of the more primitive species the germ band doubles upon itself ventrally at an early stage and sinks into the yolk in the form of an inverted **U**, in which position it may remain until the embryo is almost fully formed. A simple procedure of this sort occurs with the little insects known as springtails, an embryo of which is shown at A of Figure 16, taken from the work of Philiptschenko. It is significant to note that this method is characteristic also of centipede embryos and of the embryos of many arthropods other than insects. Another of the lower insects, the fish moth, or more entomologically, Lepisma, begins its development on the surface of the egg in the usual manner, but it too soon curves and sinks into the yolk (fig. 16 B), as shown in an account of its development by Heymons. Lepisma, however, sinks so deeply into the egg that a part of the surrounding thin blastoderm is turned in also, and the mouth of the cavity closes to a small pore. Later, the Lepisma embryo partially emerges and completes its development with its head and thoracic parts again on the surface (C). Many insects that develop entirely on the surface have the tail end bent forward as if they had, at some time in their past history, likewise partially emerged from a sunken position.

Again, there are embryos of other orders of insects that turn into the yolk tail end first (D) and stretch out within it in a reversed and inverted position (E), in which position they remain until some time before they are ready to hatch, when they revolve back to the surface of the egg (F).

The usual style of embryonic protection among insects, however, is by means of covering membranes that grow over the embryo from the surrounding thin part of the blastoderm. In typical cases of this kind a fold of the blastoderm grows out around the sides of the germ

band (fig. 16, G), the edges of which come together beneath the band and unite below it (H). The corresponding layers of the folds then become continuous, and the embryo is now shut in beneath two cellular membranes (I). The outer membrane is called the *serosa* (*Ser*), the inner, the amnion (*Am*). The serosa commonly separates from the entire surface of the yolk, forming a complete envelope about the egg inside the vitelline membrane, the amnion covering usually only the ventral part.

There are many other variations in the details of the formation of the embryonic coverings in the eggs of different species of insects, but since these protective membranes have nothing to do with the true history of development, we need say no more about them here,

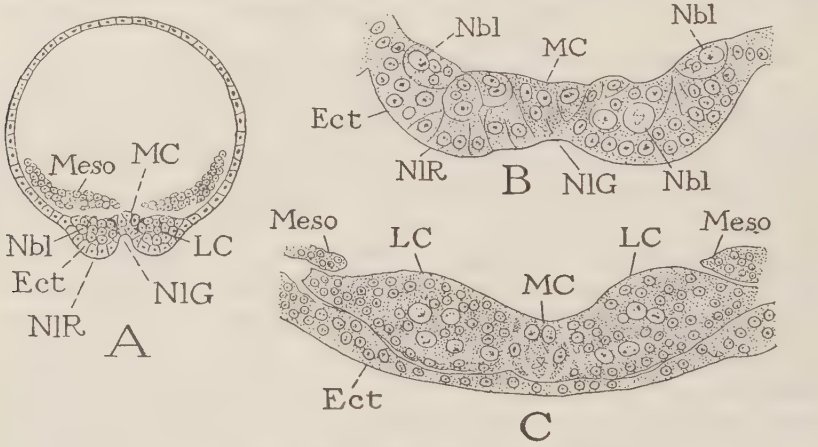

FIG. 17.—The origin of the central nervous system

A, diagrammatic cross section of young embryo, showing ventral neural ridges (*NlR*) and median neural groove (*NlG*), with masses of primitive nerve cells, or neuroblasts (*Nbl*) separated from the ectoderm (*Ect*) of the ridges and groove, forming two lateral cords (*LC*), and a median cord (*MC*).

B, Cross section through ventral part of young bee embryo, showing neuroblast cells (*Nbl*) separating from cells of ectoderm (*Ect*) in the neural ridges and groove. (Figure from Nelson.)

C, cross section through older bee embryo, showing the ventral nerve trunk, consisting at this stage of the lateral cords (*LC*) and median cord (*MC*) entirely separated from the ectoderm (*Ect*) of body wall. (Figure from Nelson.)

except to note that they are usually broken up, or are drawn back into the yolk where they are absorbed, before the young insect hatches.

THE NERVOUS SYSTEM

It is most interesting to learn from embryology that the tissue of the central nervous system, which in the adult is entirely inclosed within the body, is derived from the ectoderm. Yet, if the development of the individual follows the path of ancestral evolution, this should not be surprising, because the outer surface of the animal, being the part that comes into contact with the environment, should be the part in which sensitive tissues would be most likely to develop.

In the insect embryo, after the mesodermal groove has closed, there appears another median ventral groove along the entire length of the germ band (fig. 17A, *MdG*), while a ridge (*MdR*) swells out on each side of it. Large cells now separate internally from the ectoderm of the ridges and the groove, which are the primitive nerve cells or *neuroblasts* (*NBl*). The neuroblasts multiply and form strands of smaller nerve cells along the midline of the embryo between the ectoderm (*Ect*) and the mesoderm (*Meso*), and these strands of nerve tissue are the foundation of the central nervous system of the insect. There is a lateral cord (*LC*) generated in each ridge, and a median cord (*MC*) formed above the median groove. Figure 17 A shows the relation of these various tissues in a diagrammatic way; at B and C of the same figure, taken from the work of J. A. Nelson on the honeybee, the developing nerve cells are shown more as they actually appear in cross sections.

Note that the position of the central nerve cord of insects (fig. 21, *VNC*) is just the opposite of that of the nerve cord of vertebrates. Are the nervous systems of these two groups of animals, therefore, of independent origin, or do insects and other invertebrates with a ventral nervous system, and vertebrates with a dorsal nervous system carry themselves in reversed attitudes?

Almost from the beginning, the insect nervous system shows a segmentation corresponding with that of the body; indeed, the nerve segments are often more conspicuous than the body segments. The segmental nerve cell masses are known as *ganglia*, and the connective parts as *commisures*. Each segment at first contains a pair of ganglia (fig. 18 A. *Gng*), and the two of each pair are connected crosswise by a pair of connective strands (*Con*), besides being connected with the preceding and following ganglia by the commisures (*Com*). In the first head segment an optic ganglion (*OpGng*) is formed on each side between the central ganglia and the ectodermal rudiments of the eye (*E*).

As the embryo develops, the simple and primitive condition of its nervous system is more or less obscured and lost by a uniting and condensing of some of the ganglia into larger and more complex ganglionic masses. First, the central ganglia of the first three head segments (the segments of the procephalon) and the optic ganglia unite to form the brain of the adult (fig. 18 B, *Br*). Next, as the segments bearing the mouth appendages become added to the head, the ganglia of these segments unite to form the second compound ganglionic mass of the head (*SœGng*). When the anterior part of the alimentary canal is formed (fig. 20 B, *Stom*) it grows inward between the crosswise connectives of the second and third pairs of brain ganglia. As a consequence the connectives of the third ganglia

form a loop beneath the œsophagus (fig. 18 B, 3 *Con*), and the second nerve mass of the head also lies below the œsophagus, for which reason it is known as the subœsophageal ganglion (figs. 18 B, 21, *SoeGng*). The pair of ganglia in each body segment of the adult condenses into one segmental ganglion. These segmental ganglia may all remain separate, but usually some of them draw together and unite, though in different combinations in different insects. The

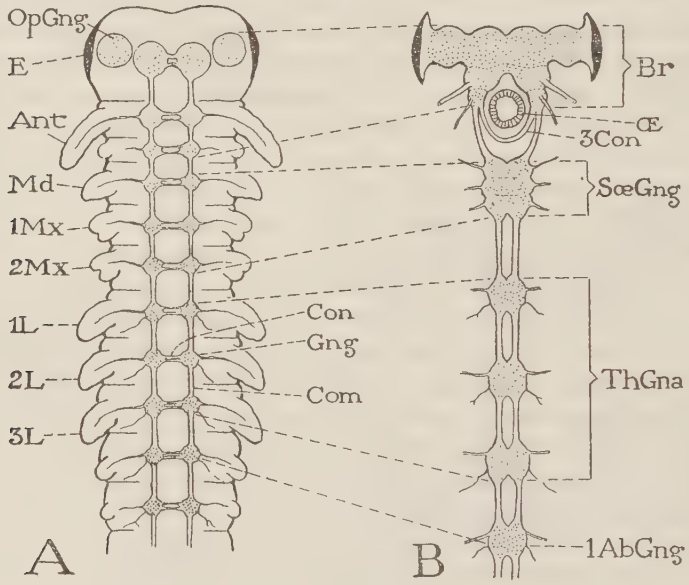

FIG. 18.—Diagrams showing the development of the central nervous system of an insect

A, the nervous system at a stage when it consists of paired segmental ganglia (*Gng*) united by lengthwise commissures (*Com*) between segments, and by crosswise connectives (*Con*) in each segment, with lateral optic ganglia (*OpGng*) in addition to median ganglia in first head segment. (Other symbols as on Figure 14.)

B, the mature nervous system, consisting of a brain (*Br*) formed of first three pairs of segmental ganglia and the optic ganglia (A), a subœsophageal ganglion (*SœGng*) formed of the three pairs of mouth part ganglia (A), and of a series of double ganglia in the body segments, the first three (*ThGna*) in the thorax, the rest in the abdomen. The cross connective of the third brain ganglia (*3Con*) lies behind the œsophagus (*Œ*), because the stomodeum (fig. 20 B, *Stom*) penetrates between the second and third pairs of head ganglia.

first three ganglia following the head belong to the thorax (fig. 18 B, *ThGna*), and the rest to the abdomen. There are seldom more than eight separate ganglia in the abdomen, since the terminal ones unite into a compound ganglion.

A creature, now, with its nervous system buried within its body, must find itself again in need of means of communication between the nerve centers and the outlying parts of its system. To supply a part of this need, nerves grow out from the ganglion cells to the

other organs, and these nerves, carrying stimuli outward, are collectively the motor nerves. To receive information from the exterior, it is necessary that there should be another set of sensory nerves. These nerves ordinarily have their origin in cells of the ectoderm and grow inward to the central ganglia, but the development of the sensory nerves in insects is not definitely known.

THE BODY WALL

The body wall of an insect deserves especial consideration for several reasons: First, it serves as a protection against the outer world, and its modifications of form distinguish the great host of insect species from one another; second, it serves as a skeleton for the attachment of the body muscles; and third, it is the seat of a great variety of sense organs.

The ectoderm layer of the embryo eventually covers the entire surface of the body and forms also various ingrowths that become

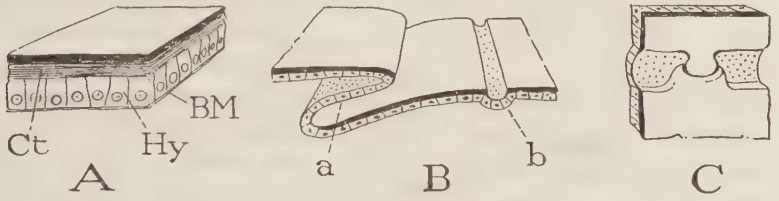

FIG. 19—Structure of the body wall of an insect

A, piece of body wall, showing outer chitinous cuticula (*Ct*), cellular hypodermis (*Hy*), and inner basement membrane (*BM*). B, movable "joints" of the body wall: *a*, fold, as between segments, where cuticula is soft and flexible; *b*, a membranous suture. C, a ball-and-socket articulation between hard parts otherwise united by membrane.

organs or parts of organs of the interior. The nervous system, as we have just seen, is one of these external derivatives of the ectoderm; others, we shall see presently, are the anterior and posterior parts of the alimentary canal, the tracheal system, various glands, and the outlet ducts of the reproductive organs. The part of the ectoderm that remains at the surface to form the body wall is commonly known in insect anatomy as the *hypodermis* (fig. 19 A, *Hy*). The cellular hypodermis is lined by a thin basement membrane (*BM*), and it forms over its outer surface a chitinous covering, the *cuticula* (*Ct*), the three layers constituting the body wall.

The character of the body wall of an insect is due to the texture of the cuticula. In caterpillars, maggots, and other soft-bodied insects, the cuticula is soft and flexible; in most adult insects it is hard and hornlike. The body of the insect, however, is not incased in a continuous shell, the areas of hard cuticula being interrupted by lines of soft cuticula. At some places the dividing lines are but

narrow sutures (fig. 19 B, *b*), but at other places, as between the body segments, the soft "membranous" areas are infolded (*a*), producing a movable joint. In many cases the hard parts of the skeleton are articulated by ball-and-socket joints, as at the bases of the jaws and between the segments of the legs, but an articulation of this sort in an insect is merely one between two extensions of the hard cuticula from the opposing edges of the neighboring plates (fig. 19 C) on the outside of the continuous though membranous part of the body wall. The articulations in the skeleton of insects are thus of quite a different nature from the joints of a vertebrate skeleton.

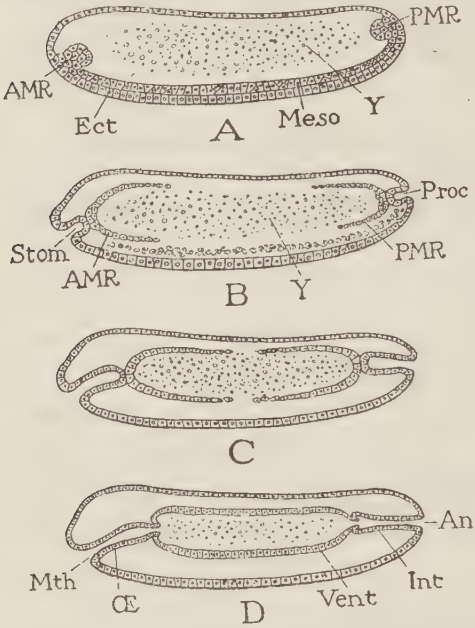

FIG. 20.—Formation of the alimentary canal (diagrammatic lengthwise sections)

A, the ventral blastoderm differentiated into ectoderm (*Ect*), mesoderm (*Meso*), and a mass of cells growing inward at each end, the anterior and posterior mesenteron rudiments (*AMR* and *PMR*). B, mesoderm disappearing along midline; mesenteron rudiments extending as cups around the yolk (*Y*); an ectodermal ingrowth taking place at each end of embryo, the stomodeum (*Stom*) in front, the proctodeum (*Proc*) behind. C, stomodeum and proctodeum deeper; lips of mesenteron rudiments approaching each other. D, mesenteron rudiments united about yolk to form the stomach, or ventriculus (*Vent*); stomodeum and proctodeum opened into stomach, the first becoming the œsophagus (*Œ*) and associated parts of alimentary canal (fig. 21) opening from mouth (*Mth*), the second the intestine (*Int*) opening to exterior through the anus (*An*).

The various kinds of hairs, spines, and scales that may cover the body and appendages of an insect are outgrowths of the cuticula. Internal ridges and arms that brace the skeleton or furnish attachment points for muscles are ingrowths of the cuticula within infoldings of the hypodermis. All the sense organs of insects are products of the ectoderm, and consist of both cuticular and hypodermal parts, the sensory cells being specialized hypodermal cells with nerve connections.

THE ALIMENTARY CANAL

To follow the development of the embryo in all its parts at the same time would be something like trying to follow the plot in one of those old-fashioned novels that drags along through the lives of a dozen or more characters and only lets you know what they all

have to do with one another in the last chapter. Since this account is not written as a mystery story, it is necessary to mention some things before we come to them, and go back continually and begin over again with each set of organs.

The alimentary canal has been developing along with the appendages, the nervous system, the body wall, and other parts not yet described. Its rudiments appear very early, soon after the mesoderm is formed, as two masses of cells that grow inward, one at each end of the latter (fig. 20A, *AMR*, *PMR*). These cell masses probably belong to the same layer of cells as the mesoderm—i. e., they and the mesoderm together may constitute the second or inner embryonic layer. This is clear in the embryos of animals that have a simpler form of development than insects. Anyhow, the two cell masses are destined to form the stomach of the insect, and for this reason they should be the endoderm. They are called the anterior and the posterior *mesenteron rudiments* (*AMR* and *PMR*), since embryologists prefer to call the insect stomach the "mesenteron," which is scientific Greek for "mid intestine." As the stomach rudiments grow, the first backward, the other forward in the interior of the embryo (fig. 19 B), they take the form of cups in some species and of long bands in others, the edges of which overlap the yolk (*Y*), and come together all around the latter (C), and finally completely inclose it (D). The yolk thus comes to be contained in a closed sac of endodermal tissue, and this sac is the stomach (D, *Vent*), usually known in the adult insect as the *ventriculus*, which is scientific Latin for "little stomach." From now on the yolk, which is the food of the embryo, must be absorbed through the walls of the stomach in order to reach the other growing tissues.

The mature insect, however, needs more than a stomach for alimentary purposes. Since it must acquire its food from without, there must be an intake opening from the exterior at one end, and likewise an opening through which waste parts of the food may be ejected. At the time the stomach rudiments are developing, or in some species before they appear, there is formed a hollow, tubular ingrowth of the ectoderm at the base of each, which elongates inward with the stomach rudiments attached to its inner end (fig. 20 B, C). The anterior ingrowth is known as the *stomodeum* (*Stom*), the posterior one as the *proctodeum* (*Proc*). Before the insect hatches, usually the inner ends of the stomodeum and the proctodeum open into the corresponding ends of the stomach (*D*), and the insect in this manner comes to acquire a continuous alimentary canal open at each end to the exterior, the stomodeum becoming the gullet, or œsophagus (*Œ*), and the protodeum the intestine (*Int*). With some

insects, such as bees and wasps, whose larvæ live in cells, and parasites of the same order whose larvæ live in the bodies of other living insects, the opening between the stomach and the intestine is not made until near the end of the larval life.

In adult insects, the stomodeal part of the alimentary canal becomes differentiated into a pharynx, a true œsophagus, a large saclike crop (fig. 21, *Cr*), and often a fourth part, or proventriculus. Likewise, two parts are usually distinguished in the intestine. From the anterior end of the latter there grow out a varying number of excretory tubes, the Malphigian tubules (fig. 21, *Mal*). All the parts derived from the ectodermal stomodeum and proctodeum are characterized by being lined with an intima continuous with the cuticula of the outer body wall. The stomach, being of endodermal tissue, has no such lining.

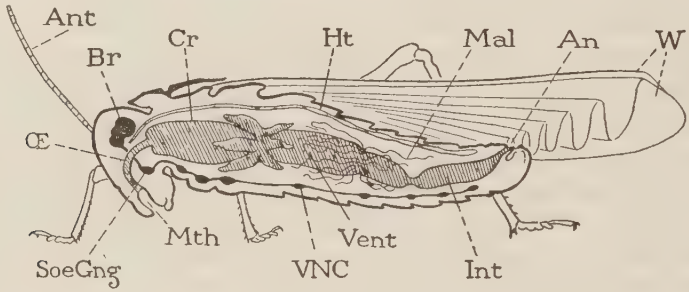

FIG. 21.—Diagrammatic lengthwise section of a grasshopper, showing general location of principal internal organs

An, anus; *Ant,* antenna; *Br,* brain; *Cr,* crop (a part of the stomodeum); *Ht,* heart; *Int,* intestine; *Mal,* Malpighian tubules; *Mth,* mouth; *Œ,* œsophagus; *SoeGng,* subœsophageal ganglion; *Vent,* stomach (ventriculus); *VNC,* ventral nerve cord; *W,* wings.

THE RESPIRATORY SYSTEM

The chemical changes that the protoplasm of living things undergoes in the process of keeping alive require a supply of oxygen and produce an excess of carbon dioxide. Hence, there goes on a constant "exchange" or respiration of these gases between the organism and the outer world. Small, soft-bodied animals, and embryos within the egg respire directly through the skin. But most animals in the adult stage have some special anatomical arrangement for bringing the outside air into the body where the tissues will have closer or easier access to it. Some have adopted and evolved one method, some another. Insects have developed a system of air tubes, or tracheæ, that branch profusely throughout the body (fig. 22) and end in thin-walled tracheoles on all the tissues that need oxygen for their maintenance.

The tracheæ are ingrowths of the ectoderm and appear first as pits along the sides of the body. The pits deepen into tubes, the tubes fork out into branches, the branches subdivide until the tracheæ from each opening, or spiracle, become a finely branched system like the roots of a plant. In most insects, some of the first branches unite with corresponding branches from successive and opposite spiracles, thus producing lengthwise and crosswise connecting trunks.

It is not certain whether the primitive spiracles are to be regarded as segmental or intersegmental in origin; they are later subject to considerable shifting of position, though in general they remain on the sides of the segments. There are usually two pairs on the thorax and eight on the abdomen in adult insects (fig. 29 *Sp*), but there is evidence to suggest that there was originally a pair of spiracles to each of the segments. The tracheæ, being of ectodermal origin, are all lined with a continuation of the cuticula of the body wall.

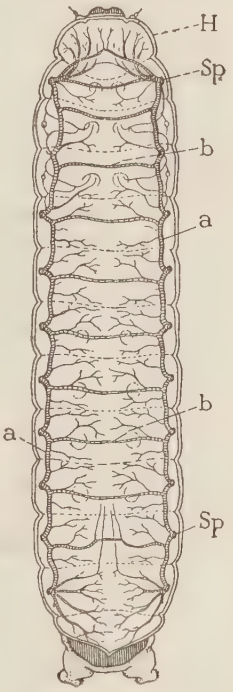

FIG. 22.—Respiratory system of a caterpillar, showing the large tracheal trunks (*a*) along sides of body, the crosswise connectives (*b*), the principal smaller branches in head (*H*) and in the lower half of body, and the series of breathing apertures, or spiracles (*Sp*), on each side.

ECTODERMAL GLANDS AND ŒNOCYTES

A great variety of glands are found in insects that open on the surface of the skin or parts derived from the ectoderm. Chief among these are the salivary glands opening near the mouth and the glands of the female that form a substance used either to glue the eggs to a support or to make a covering for them. Other glands, however, form disagreeable-smelling substances, the odor of which is supposed to ward off enemies, and some glands secrete substances that are used as food by other members of the species or by members of other associated species. Honeycomb is a waxy product of glands in the wall of the abdomen of worker bees, and the same bees feed the brood with a "royal jelly" secreted by glands opening into the mouth. All these glands are simply ectodermal cells that have acquired special functions. Some glands are one-celled (fig. 23 A, *Gl Cl*) and remain flush with the surface, perhaps penetrated by a tubular ingrowth of the surface cuticula,

which serves as an outlet canal, or duct (*Dct*). Others are simple, hollow, tubular, or saclike ingrowths of the body wall (B), while still others are of the same nature but are complicated in form by being branched or by having secondary outgrowths from the main tube (C), the latter often being enlarged to form a reservoir (*Res.*).

Not much is known concerning internal ductless glands in insects, but many species have certain large, free cells within the body cavity, known as *œnocytes*, which appear to be of this nature. Most investigators claim that the œnocytes arise from the ectoderm of the embryo along the sides of the body. If they are glandular in function, they are probably, then, ectodermal glands cells de-

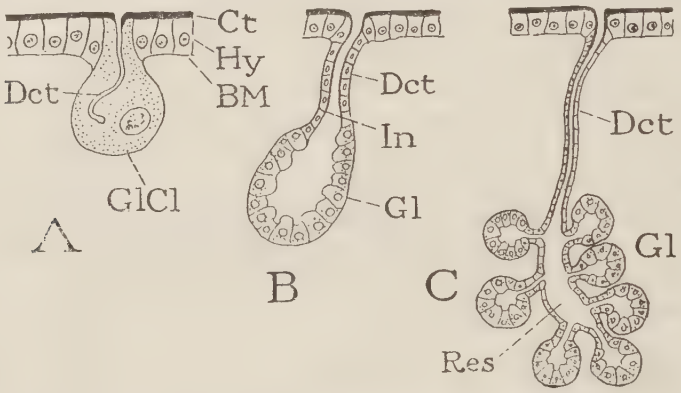

FIG. 23.—Three types of insect glands derived from the ectoderm. A, a one-celled gland (*GlCl*) which is an enlarged cell of the hypodermis (*Hy*), containing often a tubular ingrowth (*Dct*) of the cuticula (*Ct*) serving as an outlet duct. B, a simple many-celled gland (*Gl*) formed as a hollow ingrowth of the body wall, in which the cuticula becomes the lining intima (*In*), and the narrowed neck serves as a duct (*Dct*). C, a compound many-celled gland produced by a branching of type B, often with an enlarged part of the common duct (*Dct*) serving as a reservoir (*Res*).

tached from their original sites and become free, internal, one-celled organs. In the head, just behind the brain, there is a pair of small cellular bodies, known as the *corpora allata*, likewise derived from the ectoderm, and these, too, are often supposed to be internal ductless glands.

THE MUSCLES

The muscle tissue is derived from the mesoderm, though it later becomes intimately attached to the ectoderm. The mesoderm is at first usually a solid layer of cells (fig. 13, C, E, F, *Meso*) in the ventral part of the young embryo, continuous from one side to the other, but as it grows upward in the sides it breaks apart in the middle and leaves an empty space beneath the alimentary canal.

The mesodermal wings then become split into outer and inner layers, and the spaces between them, joined with that just noted beneath the alimentary canal, constitute the body cavity of the insect (fig. 24, BC). The outer mesoderm layers (*EMeso*) become applied to the body wall; the inner ones (*IMeso*) to the wall of the alimentary canal (*End*). From the first are formed principally the muscles of the body and appendages, and the fat tissue; the second forms the muscles of the stomach, and the reproductive organs.

A muscle consists of fibers, and each fiber appears to be a highly specialized cell, except for the fact that it contains many nuclei. Investigators differ as to whether the fiber is a product of many cells that have united, or whether it is a single cell, the nucleus of which has many times divided without accompanying division of the cell itself. In either case the building of the complex muscular system of the adult, perfectly adjusted to all the mechanical needs of the insect, from the layers of simple mesodermal cells is one of the most remarkable things in insect development.

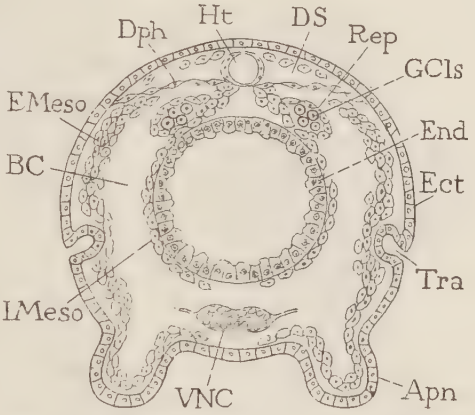

FIG. 24.—Diagrammatic cross section through abdomen of an embryo when internal organs are mostly defined

Apn, segmental appendage (if present); *BC*, body cavity; *Dph*, dorsal diaphragm; *DS*, dorsal sinus; *Ect*, ectoderm; *EMeso*, external mesoderm layer (somatic layer); *End*, stomach (endoderm); *GCls*, germ cells; *Ht*, heart; *IMeso*, inner mesoderm layer (splanchnic layer); *Rep*, reproductive organ; *Tra*, outer end of trachea and opening to exterior (spiracle); *VNC*, ventral nerve cord.

THE FAT TISSUE

In the body cavity of insects there is a widely scattered tissue consisting of large cells, sometimes compactly united, sometimes loosely held together, that constitutes what is ordinarily called the "fat body." The name is only partly appropriate, for, though the cells always store up within them a large amount of fatty oil (fig. 25, *Ft*), they also form and hold in storage proteid materials in the form of small granules (*Alb*) and, in some insects, animal starch or glycogen. The fat body is really an organ for elaborating reserve food materials, and is of greatest importance in those insects that change from a wormlike larva to the adult through an intervening pupal stage. The materials in the fat cells then serve as nutriment during the reconstructive period, when the insect takes no food.

The fat tissue is derived from the mesoderm. It is present only in small amount in the embryo, but increases rapidly in the young insect after hatching, often forming great masses filling all available space in the body cavity, particularly in the larvæ of those insects that must prepare for a final metamorphosis into the adult.

THE CIRCULATORY ORGANS

Different kinds of animals do not necessarily have every system of organs equally developed. The insect, for example, has an elaborate respiratory system, but its circulatory equipment is comparatively meager. Its "blood" is the slightly tinted liquid that fills the body cavity and directly bathes the tissues in the latter. This fluid is kept in circulation by a long pulsating tube, or heart, lying just beneath the midline of the back.

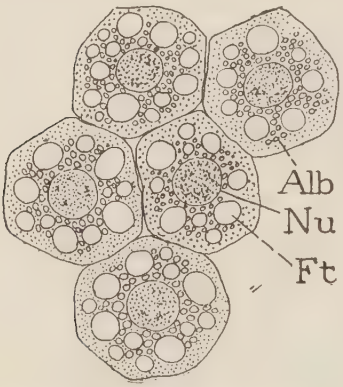

FIG. 25.—Typical fat cells of an insect during a stage preceding metamorphosis: The cell protoplasm filled with globules of fatty oil (*Ft*) and smaller granules of proteid material (*Alb*)

As the upper undivided edges of the mesoderm layers approach each other from opposite sides in the dorsal part of the embryo, their apposing faces become hollowed lengthwise, and when finally the two layers meet the edges unite to form a tube about the space between them. This tube is the heart (figs. 24, 27, *Ht*). The mesoderm cells extending outward from the heart on each side are reduced to thin sheets, together forming the diaphragm (*Dph*), a membrane in the adult, in which are developed fan-shaped bundles of muscle fibers attached at one end to the body wall and at the other to the ventral wall of the heart. The diaphragm shuts off a space, the dorsal sinus (fig. 24, *DS*), in the upper part of the body, which incloses the heart, and the blood must, therefore, first enter the dorsal sinus before it enters the heart. It gains access to the former either through open spaces along the edges of the diaphragm or through perforations of the latter, and it then enters the heart through apertures in the sides of the heart walls. In the abdomen the heart becomes segmentally enlarged into chambers, but in the thorax it remains tubular and extends into the head where it opens beneath the brain.

The course of the blood and the structure of the heart in the adult insect are shown diagrammatically in Figure 26. The pulsations of

the heart suck the blood into it through its lateral openings, or ostia (*Ost*), drive it forward, and then expel it into the head. From here it percolates backward between the organs of the body cavity, goes into the dorsal sinus, and finally reënters the heart. The number of chambers in the heart varies in different groups of insects. Usually there is a pair of ostia to each chamber and one pair of "wing muscles," but these features, likewise, are not constant in different insects.

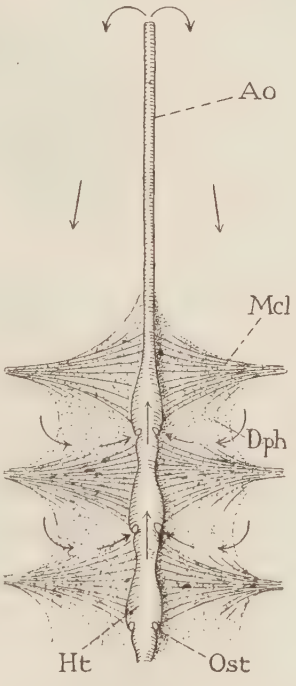

FIG. 26.—Diagram of the typical structure of the heart and diaphragm of an insect, and the course of the circulating blood (indicated by arrows)

Ao, aorta, or anterior tubular part of heart without lateral openings; *Dph*, membranous diaphragm; *Ht*, anterior three chambers of heart; *Mcl*, muscles of diaphragm, attached laterally to body wall; *Ost*, ostium, or lateral opening into heart chamber.

THE REPRODUCTIVE ORGANS

The internal parts of the reproductive organs, in which the germ cells are lodged and in which these cells undergo their development into the spermatozoa or eggs, according to sex, appear first as thickenings of the upper parts of the inner mesoderm layers in the abdominal region of the body. A strand of cells proceeds rearward from each, which becomes the duct, opening usually into a single, median outlet tube formed as an ingrowth from the ectoderm near the posterior end of the body. The germ cells (fig. 10 B, C, *GCls*), during the growth of the embryo, wander about for some time in the other tissues, but at last they come to their abiding places in the reproductive organs (figs. 24, 27, *Rep.*).

THE YOUNG INSECT

The story of insect embryology, as briefly outlined in the preceding descriptions, shows how a complex animal comes into existence from the simplest possible beginning. First, a group of primitive body cells is formed by the repeated division of a fertilized egg nucleus. These cells continue to multiply and their increasing descendants segregate themselves into other groups, which subdivide again into minor groups, until there is a group of cells representing each tissue of the adult animal. Compound organs are formed either from specialized cell groups all of the same tissue, or by the union of parts derived from cell groups of independent origin.

There is nothing visible or otherwise discernible yet discovered within the growing organism to show what endows its cells with this wonderful power of arranging themselves into a new animal, which is at the same time almost a replica of the parent form; but there is

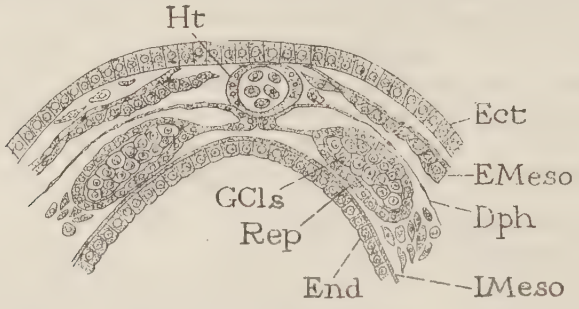

FIG. 27.—Cross section through dorsal part of abdomen of embryo of male honeybee. (Figure from Petrunkevitch)

Dph, dorsal diaphragm; *Ect,* ectoderm; *EMeso,* external mesoderm layer; *End,* stomach (endoderm); *GCls,* germ cells; *Ht,* heart; *IMeso,* inner mesoderm layer applied to stomach wall; *Rep.* reproductive organ.

also no good reason for supposing that our ignorance of the secrets of development and heredity is different from any other special case of ignorance that has been dispelled by research. There is un-

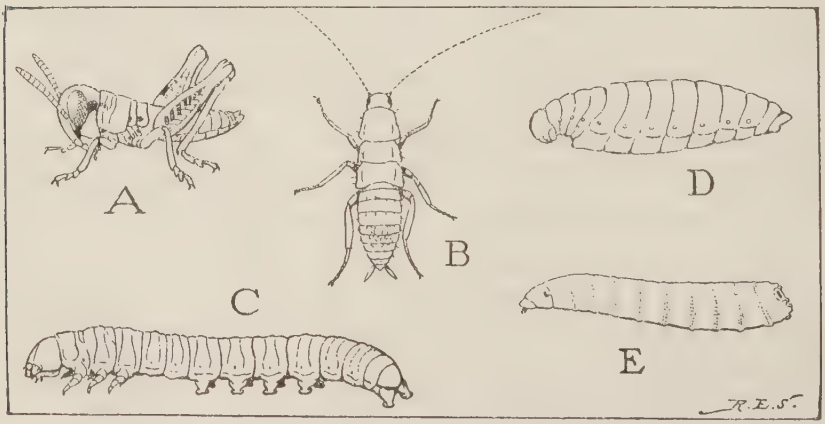

FIG. 28.—Various forms of young insects

A, a young grasshopper. B, a young roach a few minutes after hatching. C, the young of a moth (a caterpillar). D, a young wasp. E, a young fly (a maggot).

doubtedly a cause for the vital processes that transform the egg into the mature embryo, and this cause will be understandable when it is discovered, though, as with all other things in nature, it will be understandable only in terms of incomprehensible forces.

Along with the building of the tissues and organs within the body, there goes on a modeling of the external form into that which the creature will have at hatching. With most of the higher animals, the young at hatching or at birth is recognizable as the progeny of its parents, and this is true of many insects, such as grasshoppers (fig. 28, A) and roaches (B). A young fly (E), a young bee or wasp (D), or a young moth or butterfly (C), however, comes out of the egg in a form whose parentage would never be guessed from its physical characters; those insects must later undergo a transforma-

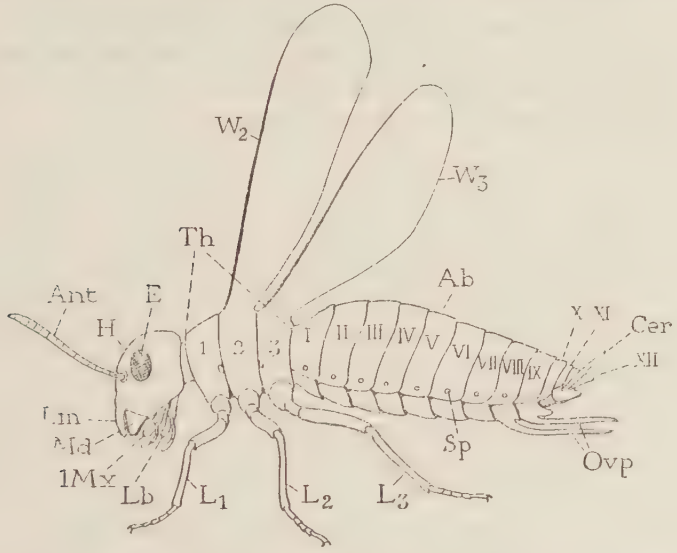

FIG. 29.—Diagram of external structure of a theoretically complete mature insect (female), showing appendages of one side only

Ab, abdomen, of 12 segments (*I–XII*); *Ant*, antenna; *Cer*, cercus; *E*, compound eye; *H*, head; L_1, L_2, L_3, legs of first, second, and third thoracic segments; *Lb*, labium (the united second maxillæ, fig. 14B, *2Mx*); *Lm*, labrum; *Md*, mandible; *1Mx*, maxilla; *Ovp*, ovipositor; *Sp*, spiracle; *Th*, thorax, of three segments (*1, 2, 3*); W_2, W_3, wings, attached to second and third thoracic segments.

tion, or metamorphosis, before they attain the form of the mature insect of their species. The double lives that such insects lead enables them to take advantage of two quite different environments during their lifetime. In the first, or larval, period the young insect specializes on feeding, and its anatomy is modeled to that end; in the second period the mature insect devotes its energy mostly to the business of mating and egg laying, and its construction is adapted to these purposes, but, being the adult, its form is already that of its species. Hence, it is clear that the form of the young is one acquired by a departure from the ancestral path. To understand the advantage of this duality to the insect, we have only to imagine how much

simpler our own existence would be if, during the first half of our life, we could earn and lay by a sufficient amount of money to be independent during the second half, when we could marry and raise families without working at anything else, and without worrying over the need of providing food, or paying the rent, or the mortgage. Insects, in fact, have adopted many advanced ideas during their evolution, and as a consequence they own the earth. The principle inconvenience of their double life is in getting from one stage into the other. This involves a process of thorough reconstruction, or metamorphosis, during which the creature is helpless and assumes the form known as the pupa. The subject of metamorphosis is one of the most interesting phases in the study of insects, but metamorphosis belongs to the postembryonic period of development and is, therefore, beyond the limits of our present theme.

THE RÔLE OF VERTEBRATES IN THE CONTROL OF INSECT PESTS

By W. L. McAtee

Assistant in charge, Division of Food Habits Research, United States Biological Survey.

[With 7 plates]

That vertebrates eat insects is common knowledge. What their destruction of these creatures means to the welfare of man, however, is appreciated by comparatively few. Indeed, even at this late date, it must be confessed that we know so little about the food habits of vertebrates other than birds that it is impossible to give a very satisfactory account of them. The unavoidable result of this situation is that the present paper while technically embracing all of the vertebrates, practically is devoted very largely to birds.

However, to give other members of the backboned clan their due, we may begin by adverting to a fact made familiar by the work of the Bureau of Fisheries, as well as by that of the Bureau of Entomology, that certain small fishes are effective enemies of mosquito larvæ, and that they can be used to advantage by man in his warfare against these pests. This seems to be the only outstanding credit to the fishes, although trout, and no doubt other fishes in infested waters, devour many black-fly larvæ. The feeding of fishes on land insects dropping into the water is of little economic significance, because desultory, and affecting individual insects, a large proportion of which would be eliminated anyway by drowning.

Among the class that is ranged next to the fishes—namely, the amphibians—we have numerous insectivorous forms, but because of their aquatic habitat many of them come but little in contact with insects injurious to man. The toads constitute a striking exception to this rule, especially the common forms that frequent cultivated fields and gardens. Toads are practically omnivorous in relation to invertebrates occurring in their habitat, and if an insect living on or near the ground is abundant enough to be the cause of damage we may be sure that any toads in the area will be feeding upon it. The common toad has a good record as a predator upon millipeds, ants,

cutworms, the army worm, tent caterpillar, gypsy caterpillar, June bugs, rose chafer, potato beetle, and the alfalfa weevil.

The food-habits of the class of reptiles are less definitely known than those of any other vertebrates. So far as snakes are concerned it appears that only a few of the smaller species are decidedly insectivorous, and they are such comparatively scarce animals that they can have but little effect upon the numbers of insects. The turtles, being chiefly aquatic, are in the same position as the water-loving amphibians—that is, they come in very slight contact with insects noxious to man. The lizards are highly insectivorous, but are rather meagerly represented over most of the United States. Some of the western and southwestern species, however, appear to be important enemies of grasshoppers and ants, and to be generally useful as insect destroyers. In hot countries lizards are more numerous, active, and voracious, and have been credited by some writers with being as valuable individually as are insectivorous birds.

Among mammals we have some highly insectivorous groups as the bats, shrews, and moles. The exact nature of the food of bats is little known but it includes all sorts of flying insects of sizes these animals can swallow, including mosquitoes, but the latter certainly to no such extent as has sometimes been claimed. Shrews and moles get numerous ants, wireworms, cutworms, and white grubs, and doubtless do more good than harm. The short-tailed shrew has proved to be one of the principal enemies of the larch sawfly and in New Brunswick, it has been ascertained that 40 per cent of the cocoons are destroyed by this shrew. Arboreal squirrels sometimes feed freely on scale insects and other tree pests; the western ground squirrels eat quantities of injurious insects, such as cutworms, wireworms, and grasshoppers; and the so-called grasshopper mice perhaps deserve their name, and undoubtedly are more highly insectivorous than the majority of their tribe. The armadillo, which occurs in the United States only in Texas, is a voracious consumer of insects, especially white grubs and their adults, caterpillars, and ants, and the badger occasionally makes a hearty meal of grasshoppers, immature cicadas, or beetles. Of our larger mammals, skunks certainly are the greatest enemies of insects. Army worms, tobacco worms, and white grubs are favorite prey of these animals. In Manitoba, Mr. Norman Criddle, field officer, Canadian Entomological Service, estimated that on one 8-acre tract skunks destroyed 14,520 white grubs to the acre. Cutworms, the potato beetle, and grasshoppers are other insect pests eaten by skunks, and the common eastern skunk once proved so efficient an enemy of the hop grub in New York, that the first

legislation protecting the animal in that State was passed at the demand of the hop growers. Investigations in New Mexico by the Biological Survey showed skunks also to be the most important natural enemies of the range caterpillar.

While we must confess that we do not know as much about the food habits of vertebrates, other than birds, as we should know and as we shall know when investigations now in progress are completed, we can safely assert that no investigation is likely to upset the present assumption that as enemies of insects, birds stand supreme among vertebrates. If for no other reasons, we are thus confident because birds are more numerous in species and individuals than other insectivorous vertebrates, and their greater mobility enables them to concentrate quickly where unusual food supplies become available—that is, at the scene of insect outbreaks.

The most extensive studies of the food of birds ever made have been carried on by the United States Biological Survey, but these investigations for the most part have been directed toward learning what birds eat in general, rather than determining the explicit effect of their food habits upon certain insects or other pests. The Survey has a great store of data as to the items of bird food, and the numbers and proportions in which they are taken; it can furnish comprehensive lists of the bird enemies of a vast number of insects, but it is not in a position to report from its own resources, what degree of control birds attain over this or that particular insect pest.

In fact opportunities to get such information come infrequently and the observers most likely to be favored are the men in the field who are working continuously upon an insect outbreak. These men, usually, are economic entomologists, numbers of whom, fortunately, have made good use of their opportunities, and it is largely upon their work that the remainder of this article is based. The writer is the more justified in quoting their findings so freely since economic ornithology, not only in this, but in other countries, has been fostered and inspired chiefly by entomologists.

Among the earliest champions of the value of birds in this country were Dr. William Le Baron, of Illinois, and Dr. Isaac P. Trimble, of New Jersey, both well-known entomologists. These gentlemen did not neglect the examination of the contents of bird stomachs, but it may be a surprise to learn that Dr. Townend Glover, first entomologist of the United States Department of Agriculture, not only examined the stomach contents of many birds, but had in the old agricultural museum a collection of mounted birds with their food in vials beside them. Furthermore, one of his annual reports, that for 1865, was devoted largely to a general account of the economic value of birds including results of his original investigations. The United

States Entomological Commission of the seventies did not fail to give due credit to bird enemies of the insect pests it studied, and in the report on the Rocky Mountain locust, gave to the world the most extensive paper on the food of birds that had appeared up to that time. The researches and philosophical writings of Dr. S. A. Forbes, of Illinois, during the eighties earned for him the name of founder of the science of economic ornithology. The Biological Survey which has carried the study of the economic relations of birds farther than has ever been done elsewhere, had its origin as a section of economic ornithology in what then was the Division of Entomology. Although this arrangement did not last long, the first two reports published by the new organization on the food of insectivorous birds contained technical sections on the insect food, written by those eminent entomologists, Dr. C. V. Riley, and Dr. E. A. Schwarz.

Not only did entomologists have much to do with the origin and establishment of economic ornithology in this country but their interest in the subject has been actively maintained to the present day. References to the value of birds are especially numerous in the writings of the later entomologists, Lintner, Slingerland, and Hewitt, among the deceased, and among the living, Weed, Bruner, Sanderson, Felt, Hopkins, and Chittenden. In Canada Dr. John D. Tothill has been especially active and has published a series of splendid papers on the natural control of insects, in every one of which birds have been given great credit.

In a recent work on the Principles of Insect Control,[1] the authors, Messrs. Robert A. Wardle and Philip Buckle, devote an entire chapter to bird encouragement. In summing up the economic status of British birds they state that the "cuckoos, swifts, lapwings, woodpeckers, and the majority of Passerine birds, particularly Paridæ (tits), Turdidæ (thrushes), Muscicapidæ (flycatchers), and Hirundinidæ (swallows), are of the utmost value" (p. 61).

Having by now made the impression, the writer hopes, that economic ornithology after all is very much an entomological subject, we will proceed to a systematic discussion of the value of birds in insect control. But while so doing we must avoid anthropomorphic reasoning to the effect that birds prey upon this or that insect to assist mankind. On the contrary, whatever they do in the way of feeding upon insects is for reasons entirely their own, but it so happens that in carrying on their customary activities they sometimes do great good in the suppression of insect pests.

We must remember also that insects are not the sole food of birds but that the birds draw on all the sources of food available to them,

[1] Manchester Univ. Press, 1923, 295 pp.

including the vegetable as well as the animal kingdom. Probably half of the total food of birds in general is of vegetable origin. Again, all sorts of animals from protozoans to mammals are eaten, and insects do not contribute more than their due proportion. In short, we must bear in mind that birds feel no obligation to help us, nor do they, as we might wish, feed exclusively upon insects. These limiting factors understood, we shall be the more able to appreciate the activities of birds at their true worth.

Despite the adaptive radiation in food habits which birds exhibit, and which leads to more or less specialization in various groups, few kinds are so absolutely bound to peculiar feeding methods that they can not forsake them temporarily when some food becomes available in unusual abundance. For a simply stated illustration of this phenomenon the writer draws on Dr. Isaac P. Trimble, the pioneer economic entomologist of New Jersey, who, in his Treatise on the Insect Enemies of Fruit and Fruit Trees, published in 1865, wrote:

> On the 5th of May, 1864, I shot seven different birds; they had all been feeding freely on small beetles, and some of them on nothing else. There was a great flight of these small beetles that day; the atmosphere was teeming with them. A few days later, the air was filled with ephemera flies, and the same species of birds were then feeding upon these (p. 113).

A more elaborate example of the same tendency on the part of birds is Prof. Samuel Aughey's findings during his studies of bird enemies of the Rocky Mountain locust in the sixties and seventies. Tempted by the abundance and accessibility of these insects, birds of every kind flocked to the feast. Land birds and water birds, tree frequenters and plains dwellers, whether normally fish, flesh, seed, or fruit eaters—all, from the diminutive humming bird to the largest hawks, came to feed upon grasshoppers.

Not only is a further striking instance of this phenomenon recorded by Dr. S. A. Forbes as a result of his study of birds in relation to cankerworms in Illinois, but the conclusions to be drawn are stated so clearly as to be well worth quoting. Dr. Forbes says:

> Birds of the most varied character and habits, migrant and resident, of all sizes, from the tiny wren to the bluejay, birds of the forest, garden and meadow, those of arboreal and those of terrestrial habit, were certainly either attracted or detained here by the bountiful supply of insect food, and were feeding freely upon the species most abundant. That 35 per cent of the food of all the birds congregated in this orchard should have consisted of a single species of insect, is a fact so extraordinary that its meaning can not be mistaken. Whatever power the birds of this vicinity possessed as checks upon destructive irruptions of insect life was being largely exerted here to restore the broken balance of organic nature.[2]

[2] Forbes, S. A.: The Regulative Action of Birds upon Insect Oscillations, Bull. Ill. State Laboratory of Natural History, Vol. I, No. 6, May, 1883, pp. 20–21.

Whether the pressure thus put on irruptions of insects is ever effective in securing a worth while degree of control is a topic upon which it is natural to be skeptical. Insects are so numerous and propagate so rapidly that it would seem they would always evade control by so limited a force as the bird population. Yet when we consider the results of the feeding habits of birds in other and more easily observed directions we begin to see that their consuming capacity is certainly impressive. For instance, consider the devouring of wild fruits by birds; it is quite the customary thing for a flock of birds to resort constantly to a certain tree or group of trees for food until the entire crop of fruit is consumed. This process is illustrated nearly every year in the parks of Washington. When the spring migrating impulse is on, cedar birds usually come to the parks in large numbers, and it is their habit to devote themselves to one kind of berry until it is gone. For instance, should they begin on holly they will finish all the holly berries in the Smithsonian Grounds, let us say, then they will next be found in the Capitol Grounds or in some other park working on the hollies there. Then they may turn their attention to cedar berries, if there is a crop, or to barberries, or to other fruit available. I have observed in various years that after cleaning up the berries they have even consumed the pods of the Sophora trees, feeding wastefully upon them at first, but later descending to the ground to go over again the remnants of the feast. I have seen on different occasions flocks of blackbirds, or of purple finches, or robins consume the entire crop of dogwood berries, not only of one or a few trees, but of all the trees in a woodland. Indeed, this manner of feeding is quite characteristic of birds.

If birds can do such things, if they consume in a brief time all the berries on a tree, is it not equally possible that they can consume likewise all of the insects? The answer is an emphatic and indisputable "yes." Such clean-up work not only can be, but has been done, and there is here given a summary of the recorded instances so far as they have been assembled.

For convenience the cases are arranged by orders of insects, and it will be understood when the word control is used, that our authority has made a statement indicating a high degree of control, and the word suppression when the insect concerned has been locally extirpated. The latter cases have already been treated at length in an article entitled "Local Suppression of Insect Pests by Birds," published in the Smithsonian Report for 1920.[3] All data used in the following notes on control pertain either to the United States or Canada.

[3] 1922. Pp. 411–438, 3 pls.

TERMITES OR WHITE ANTS (ISOPTERA).

At least three times the writer has personally made the observation, and he has had similar reports from others, that English sparrows, discovering a swarm of winged termites emerging from the nest, prey upon them so persistently that but few individuals escape.

GRASSHOPPERS AND CRICKETS (ORTHOPTERA).

There are at hand 31 instances of control and 19 of suppression of these insects in 13 States and 1 Canadian province. Among the authorities for the statements are included the following entomologists: Prof. Cyrus Thomas, Prof. Lawrence Bruner, Dr. E. Dwight Sanderson, Mr. Norman Criddle, Dr. H. C. Severin, and Messrs. A. C. Burrill, J. R. Horton, C. E. Pemberton, C. L. Corkins, and Max Reeher. Doctor Sanderson, in his report[4] on the differential locust (*Melanoplus differentialis*) in Texas, states that birds "undoubtedly did more than any other natural agency to check the pest." Mr. Reeher remarks that birds were so efficient in controlling the coulee cricket (*Peranabrus scabricollis*) in the Dry Coulee region, Washington State, in 1918, that arrangements for a 1919 control campaign were abandoned. Meadowlarks were almost entirely responsible for a complete clean-up of the area.[5]

Mr. C. C. Clute relates the following instance of money saved through attracting bird enemies of grasshoppers in Iowa:

> I know one farmer in particular who lost during one summer three rows of corn 40 rods long. The corn grew next to a fence row heavily sodded with bluegrass, which produced swarms of grasshoppers. For the sake of the experiment alone, for this farmer was a skeptic, last spring he put up 21 bird houses, placed 2 rods apart, on the fence along the 40 rods. The houses were some that he and the boys had made, during the winter months, from dry goods boxes obtained in town. Thirteen of the 21 houses were inhabited during the following summer, 6 by wrens, 4 by bluebirds, and 3 by colonies of purple martins. The grasshoppers that summer made a rich living for the birds, and when the fall came that farmer had the satisfaction of gathering 23 bushels of corn from the three rows that grew next to the fence, right where there had been no corn at all the year before.[6]

An account of bird control of Orthoptera can hardly omit reference to the historic case of suppression of the Mormon cricket (*Anabrus simplex*) by California gulls in the early days in Utah. Hon. George Q. Cannon, speaking of this insect and its bird enemies

[4] Bull. 57, U. S. Bur. Ent. 1906, p. 22.
[5] In Burrill, A. C. Calif. Fish and Game, 6, No. 1, Jan., 1920, p. 38.
[6] Iowa Conservation, January–March, 1917, Vol. I, No. 1, p. 12.

in an address before the Third National Irrigation Congress, in Denver, 1894, said:[7]

> After our grain had been sown and our fields looked promising, black crickets came * * * by the millions and devoured our crops. I have seen fields of wheat as promising as they could be in the morning and by evening they would be as bare as a man's hand—devoured by these crickets. * * * To us who lived in Utah about that time it seemed there was a visitation of Providence to save us. Sea gulls came by hundreds and by thousands, and before the crops were entirely destroyed these gulls devoured the insects, so that our fields were entirely freed from them.

This testimony is corroborated by that of a correspondent of the first entomologist of the United States Department of Agriculture, Dr. Townend Glover, who records[8] that "Mr. James McKnight, who lives in Salt Lake City, states that when the Mormons first emigrated to Utah this cricket appeared in immense swarms, destroying their whole crops of wheat, etc., and that the second year they also appeared, but providentially, or miraculously, as it was deemed by the Mormons, vast flocks of white gulls suddenly appeared and destroyed the crickets to such an extent as to almost eradicate them for the time being, thus saving the remainder of the crop, upon which alone the half-starved Mormons had to rely for food for the next season. Since that time these birds are held almost sacred in Utah." It may be added that a monument commemorating the valuable aid of the gulls has been erected in Salt Lake City at a cost of $40,000.

CICADAS, PLANT LICE, ETC. (HOMOPTERA)

Among entomologists, Dr. John B. Smith, Prof. F. M. Webster, and Dr. C. R. Marlatt agree that the periodical cicada is practically doomed to extinction in city parks or other localities where numerous English sparrows have a chance at them. Five cases of practically complete local extirpation of this insect by these sparrows are on record for the States of Illinois, Ohio, New York, and the District of Columbia. Doctor Marlatt also records the absolute failure of these insects to establish themselves even after artificial planting of enormous numbers in the Agricultural Grounds, because of the attacks of crow blackbirds.

For the pear psylla Prof. M. V. Slingerland gives an instance of control by birds in New York, Mr. E. H. Forbush one of the suppression in Massachusetts, and Mr. H. A. Surface another for New York State. An account of the latter instance is of value in showing how birds were put to practical use in solving a problem in economic entomology.

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[7] Irrigation Age, Vol. VII, No. 4, pp. 188–189, Oct., 1894.
[8] Rep. Commr. Agr., p. 79, 1871.

A prominent grower of pears in New York reported to us that he had lost many of his pear crops, amounting to thousands of bushels, by this pest, and in the fall, as it was present in great numbers on the trunks of the trees, it appeared that it would pass the winter there and destroy his crops again next year. However, the white-breasted nuthatches came to the orchard in numbers, and he encouraged them to remain by fastening pieces of fat meat in his trees and protected them from molestation. The nuthatches remained and fed on the pest all winter and cleaned up the trees so effectively that he could scarcely find any of the insects in the spring.[9]

In the case of plant lice we have one record by Mr. H. A. Surface, of control of the apple aphis, in Pennsylvania, and the following 5 cases of suppression: Pea louse, one in Massachusetts, by Mr. E. H. Forbush, and one in New Jersey, Dr. John B. Smith; rose aphis, one in California, Mr. H. M. Russell; and unidentified aphids, one in Washington State and one in Massachusetts.

The writer has made one investigation of the bird enemies of plant lice, the insect being the green bug or wheat aphis. On a 200-acre farm in North Carolina, where wheat, rye, and oats were severely attacked by green bugs, it was found that birds were very effective in destroying the pests. The outbreak was at its height during the migration season of such birds as the goldfinch and the vesper and chipping sparrows, which with other species on the farm numbered more than 3,000 individuals. It was found that these birds were destroying green bugs at the rate of nearly a million a day, and on days when additional flocks of migrants were present this destruction was doubled. During the season such numbers of birds flocked to the grain fields that the aphis infestation was reduced by an incalculable number. Destruction of the aphids was at its height during that stage of cool spring weather that permits the green bug to breed freely yet holds in check its parasites. It will readily be agreed that under such circumstances every economic entomologist would welcome the assistance of any agency that would account for one or two million green bugs daily on a single farm.

In two further items relating to Homoptera, birds are credited with being the most important enemies of the clover leaf hopper (*Agallia sanguinolenta*), and in one instance with locally extirpating black olive scales. These complete the instances on hand for the order, 3 being of control, and 14 of suppression.

TRUE BUGS (HETEROPTERA)

Contrary to the impression prevailing among many naturalists, birds feed rather freely on Heteroptera. Nevertheless, there are few instances of great activity in this direction by field observers. Prof.

[9] Zool. Bull. Penn. Dept. Agr., Vol. V, No. 3, p. 79, July, 1907.

Franklin Sherman reports[10] English sparrows as an efficient aid in keeping Harlequin cabbage bugs in check in Robeson County, N. C., and Dr. A. W. Morrill notes that his studies of natural enemies of the conchuela (*Pentatoma ligata*) "point to the strong probability that birds are the useful agents in the reduction of the numbers of the adults."[11]

BEETLES (COLEOPTERA).

For the extensive order of Coleoptera we have records of local control or suppression by birds, of beetles of nine families comprising nearly all of those including seriously destructive species. These will be taken up in order. The Biological Survey has found wireworms or adults of the family Elateridæ in the stomachs of about 170 species of birds, and the value of birds as enemies of these pests has been freely acknowledged by Mr. J. A. Hyslop, of the Bureau of Entomology, specialist on the family, who says in his bulletin[12] on "Wireworms attacking cereal and forage crops," "Probably the most imporant factor in keeping wireworms in check are the birds."

Passing to the family Buprestidæ, we have an instance by Prof. R. A. Cooley, of Montana, of effective depredations by woodpeckers upon larvæ of the flat-headed apple-tree borer (*Chrysobothris femorata*), and the statement by Dr. T. E. Snyder, of the United States Bureau of Entomology, that woodpecker enemies of the mangrove borer (*Chrysobothris tranquebarica*) often obtain a high percentage of the larvæ infesting introduced Australian pines in Florida.[13]

The long-horned wood borers also are attacked by woodpeckers, and the activities of these birds sometimes result in a considerable degree of control of the pests. Mr. Walter N. Hess says of the ribbed pine borer (*Rhagium lineatum*): "Birds, chiefly the woodpeckers, are probably the most important of the predatory enemies. It is not uncommon to find infested trees where these birds have removed from one-half to two-thirds of the larvæ and adults during a single winter."[14] Mr. Fred E. Brooks has found woodpeckers to be highly effective enemies of the round-headed apple-tree borers. Of the spotted species (*Saperda cretata*) he says:

> By far the most effective natural check to the increase of this borer seems to be the woodpeckers. The borers feed in positions easily accessible to these birds and empty burrows are to be found on almost every infested tree, with the marks of the birds around the wounds giving unmistakable evidence of the cause of the borer's disappearance. During the present studies every attempt to rear larvæ in unprotected trees met with a loss of all the individuals as a result of woodpecker attack. * * * It seems probable that the spotted

[10] Bull. N. C. Dept. Agr. 32, No. 7, July, 1911, p. 21.
[11] Bull. 86, U. S. Bur. Ent., 1910, p. 67.
[12] Bull. 156, U. S. Dept. Agr., 1915, p. 25.
[13] Journ. Agr. Research 16, No. 6, Feb., 1919, p. 161.
[14] Mem. 33, Cornell Agr., Exp. Sta., May, 1920, p. 379.

apple-tree borer would be a much more widely known and destructive pest were it not for the constant depletion of their numbers by woodpeckers.[15]

Relative to the striped species he makes still stronger statements. "While the control effect of parasites and predacious foes on this borer is negligible," he says, "woodpeckers play an important part in holding it in check. * * * In several orchards where counts were made from 50 to 75 per cent of the borers had been destroyed."[16]

Among the Chrysomelidæ or leaf beetles, probably the most notorious pest is the potato beetle and it is just the species for which we find recorded the most emphatic statements relating to birds as agents of control. There is on record one case of control in Wisconsin, and seven cases of local extermination occurring in Minnesota, Iowa, Illinois, Massachusetts, Pennsylvania, and South Carolina. There is one instance of local suppression of asparagus beetles by birds occurring in New York, one of control of the locust-leaf miner in Maryland, and four instances of effective depredations upon the elm-leaf beetle in Massachusetts. One writer had the temerity to venture that birds do not eat this beetle, but the cedar bird feeds freely upon it, in two recorded cases at least, exercising notable control of infestations and in two others entirely eliminating them.

Coming to the family Scarabaeidæ, we find that white grubs are the most frequent objects of investigation by economic entomologists and we learn also that high rank is invariably given to bird enemies of these pests. Dr. John J. Davis, a specialist on white grubs, gives birds first place among the natural enemies. Of his own observations he says:

> Fields of timothy sod have been literally overturned by crows in their search for grubs, and in some fields the grubs were almost exterminated by them. Crows have often been observed following the plow in infested fields, eagerly picking up every grub that was unearthed.[17]

Mr. Norman Criddle also writes in favor of the same bird and says that while plowing he has personally observed that fully 90 per cent of white grubs exposed were picked up by crows. He is so convinced of the value of birds in controlling white grubs that he recommends that farm practice in Manitoba be planned chiefly with a view of best utilizing the services of birds in destroying white grubs; a remarkable tribute to the effectiveness of practical economic ornithology. He says:

> Birds are most persistent followers of the plow during their breeding season or while migrating; gulls and terns from May 16 to June 22, and

[15] Bull. 886, U. S. Dept. Agr., Oct., 1920, pp. 8–9.
[16] Bull. 847, U. S. Dept. Agr., August, 1920, p. 29.
[17] Farmers' Bull. No. 543, U. S. Department of Agriculture, July, 1913, p. 13.

for a short time late in July; crows and blackbirds, including grackles, from the time grubs appear in May until July 1.

From the foregoing we reach the conclusion that to attain the best possible results under conditions existing in Manitoba, plowing should be done between May 14 and July 1, and at an average depth of 5 inches. The idea is, of course, to turn up as many grubs, eggs, or pupæ as possible, a majority of which will, in all probability, be picked up by birds.[18]

The wireworms of the Far West usually are Tenebrionid larvæ, and it is presumed these are meant in a report by Mr. A. L. Rutherford, horticultural commissioner of Stanislaus County, Calif., in which he credits blackbirds with having eradicated the wireworms in the Turlock and Modesto irrigation districts.[19]

All families of weevils contain injurious species and we have records of effective destruction by birds of members of three of the families. Of one of the Otiorhynchids, the rose beetle (*Aramigus fulleri*), Mr. John G. Tyler, of Fresno, Calif., says:

One spring vast numbers of rose beetles (*Aramigus fulleri*) invaded the country about Clovis [California], and after destroying the rose flowers they took to the vineyards, doing considerable damage to the foliage by boring numerous holes through the leaves, causing them eventually to wither up and drop off. Every day for nearly a week a great flock of Brewer blackbirds hovered over a certain vineyard that I had an excellent opportunity to observe. Crawling over the branches or alighting on the topmost shoot, these black-plumaged birds were conspicuous objects against the green of the tender new foliage. As a result of the efforts of these birds, in a short time the vineyard was almost entirely free from the beetles.

Of the Curculionids, two closely related pests are known to be eaten very freely by birds. The Biological Survey has found the clover-leaf weevil (*Hypera punctata*) in the stomachs of nearly 50 species of birds, and Messrs. D. G. Tower and F. A. Fenton, authors of a Farmers' Bulletin[20] on this weevil, consider that "Birds are valuable and important checks on this insect." In two summers' investigation in Utah of bird enemies of the alfalfa weevil by the Biological Survey, 45 species of birds were found to attack the weevil. The killdeer was one of the most active of these, making alfalfa weevils a third of its food during part of the summer; one stomach contained no fewer than 383 individuals, 376 of them in the larval stage. The record for numbers—442 in one stomach—was held by the Brewer blackbird, an abundant species in Utah. A surprising discovery was that as a species the English sparrow was the most effective enemy of this insect; alfalfa weevils formed about a third of the food upon which its young were reared, and it was estimated that the number fed to growing English sparrows on a

[18] Agr. Gaz. Can., Vol. 5, No. 5, May, 1918, pp. 449–454.
[19] Weekly News Letter, Comm. Hort. Calif., Vol. 3, No. 13, April 5, 1919.
[20] No. 922, Dec., 1920, p. 17.

typical Utah farm was about 500,000. To this must be added the number eaten by the adult sparrows, which made of them about a fifth of their food. Most of the common birds of northeastern Utah were depending upon alfalfa weevils for almost a sixth of their entire food, and the destruction of these pests by this warfare is almost beyond conception.

The good work of birds in preying upon another weevil pest, the cotton boll weevil, must not be overlooked. Sixty-six kinds of birds are known to feed upon this formidable cotton destroyer, probably the most effective being the orioles, which actually remove the boll weevils from the place where damage begins—that is, the squares, or flower buds, of the cotton plants—and the swallows, which feed upon the weevils when in flight and extending their range. No fewer than 41 boll weevils were found in a single stomach of the Bullock oriole, and large numbers are habitually taken by all species of swallows; every one of a series of 35 eaves swallows had eaten them, the largest number in any stomach being 48, and the average 19.

All the students of bark beetles *(Scolytidæ)* have been impressed with the usefulness of woodpeckers as enemies of these pests, and there are at hand six different statements indicating their control value from the pens of Dr. A. D. Hopkins, Mr. J. L. Webb, Dr. M. W. Blackman, and Dr. J. M. Swaine. We will quote only one of these, and that from Dr. Hopkins. He says with regard to the spruce-destroying bark beetle which has been responsible for the loss of many billions of feet of timber in the Northeastern States:

> The principal enemy of the spruce-destroying beetle, and other bark-infesting enemies of the spruce, consists of the woodpeckers, which destroy, it is believed, from 50 to 75 per cent of the broods of the spruce beetle in many hundreds of trees each year.[21]

FLIES (DIPTERA)

Only a single instance of control by birds of a dipterous pest has come to notice, and that is one in which artificial use was made of the birds. Dr. Samuel G. Dixon, late health commissioner of Pennsylvania, writes:

> After trying the ability of fish to devour larvæ and pupæ of mosquitoes with varied success, I built two dams near together on the same stream, so that each would have the same environment for the breeding of mosquitoes. Each covered nearly 1,400 square feet. In one 20 mallard ducks, *Anas platyrhyncha*, were permitted to feed, while the other was entirely protected from waterfowl, but well stocked with goldfish, *Carassius auratus* variety *americanus*.
>
> The one in which the ducks fed was for several months entirely free from mosquitoes, while the pond protected from ducks and stocked with fish was swarming with young insects in different cycles of life.

[21] Bull. 28, U. S. Bur. Ent., 1901, p. 48.

To the infested pond 10 well-fed mallard ducks, *Anas platyrhyncha*, were then admitted, and as they entered the pond they were first attracted by the larval batrachians, tadpoles. They, however, soon recognized the presence of larvæ and pupæ of the mosquito and immediately turned their attention to these, ravenously devouring them in preference to any other food stuffs present. At the end of 24 hours no pupæ were to be found and in 48 hours only a few small larvæ survived. The motion of the water made by the ducks, of course, drowned some of the insects—what proportion can not be estimated.

For some years I have been using ducks to keep down mosquitoes in swamps that would have been very expensive to drain, but I never fully appreciated the high degree of efficiency of the duck as a destroyer of mosquito life until the foregoing test was made.[22]

LEPIDOPTERA (BUTTERFLIES AND MOTHS)

When we use the vernacular terms butterflies and moths as equivalents of the order name Lepidoptera we obscure the fact that it is the immature stages, almost exclusively, that are of economic interest. Not only are the caterpillars most important from this point of view, but they are also most important in the food of avian predators upon this order. They are devoured by nearly all kinds of insectivorous birds and are used in quantity especially for feeding the young. They are favored for this latter purpose even by numerous birds that are not highly insectivorous when adult.

The avian attack upon the immature stages of Lepidoptera is a heavy one and, as we shall see, it has resulted in numerous observed cases of control or local extermination of various pests. Representatives of 15 families of Lepidoptera are involved in these statistics and they will be taken up in order.

The larvæ of a butterfly (*Agraulis vanillæ*) of the family Nymphalidæ were eaten so persistently by road runners in one case in California that, according to Mr. A. W. Anthony, a fence row covered with their food plant was entirely cleared of them. In another butterfly family are those well-known pests, the cabbage worms. Mr. Otto Lugger, former State entomologist, made an interesting observation on their vertebrate enemies in Minnesota. He had the position of 500 chrysalides of cabbage butterflies marked on a board fence and observed them through the winter to note their fate; by May 1 the number had been reduced from 500 to 43, a destruction of more than 90 per cent, chiefly by birds. Dr. J. Schneck observed in Southern Illinois one instance of complete elimination of worms from a cabbage patch by chipping sparrows.

Beginning the moths with the Sphingidæ we have on record one case of local extirpation of the catalpa sphinx in Alabama by cuckoos, and two of the tomato worm in Indiana by crows. One

[22] Journ. Amer. Med. Assn., Vol. 63, No. 14, p. 1203, Oct. 3, 1914.

of the latter instances was observed by Mr. Frank N. Wallace, State entomologist.

In the case of another large moth—namely, *Samia cecropia* of the family Saturniidæ—the late Prof. F. M. Webster recorded the destruction of all but two of the cocoons of this species in a grove in Illinois by hairy woodpeckers. Dr. John D. Tothill, who has published so much interesting information on natural enemies of insects, concludes that in his region (Nova Scotia) nearly three-fourths of the cecropia caterpillars are eaten by orioles, robins, and other birds, and about 85 per cent of the pupæ are destroyed by woodpeckers. When M. Leopold Trouvelot was experimenting with the so-called American silkworm (*Telea polyphemus*) he found birds to be the most formidable enemies of the caterpillars, and he says: "It is probable that ninety-five out of a hundred worms become the prey of these feathered insect hunters."[23] In one case, to test the birds, he placed 2,000 of the larvæ on a tree near his door, and in a few days the birds had eaten all of them.

Excessively hairy larvæ are characteristic of the family Arctiidæ, but at least one of them, the fall webworm (*Hyphantria textor*), is freely eaten by birds. Dr. C. Gordon Hewitt informs us that, "The study of the natural control of the fall webworm was extended to Nova Scotia in 1916, and it is interesting to record that of the different factors operating in the reduction of this insect the red-eyed vireo, *Vireosylva olivacea* L., appears to be the most important. It was estimated that about 40 per cent of the larvæ had been destroyed in the webs by this bird at the five observation points."[24]

The observations referred to are those of Doctor Tothill, who credits birds with percentages of destruction of the broods, varying in different years, from 11.4 per cent to 89.5 per cent. In 1912, when the insect was fairly plentiful, a reduction in numbers was brought about chiefly by parasites. In succeeding years the parasites gradually died out as the insect became rare, and control was maintained almost exclusively by birds.[25]

While it may not be well known that hairy caterpillars are eaten so freely by birds, it is common knowledge that cutworms are favorite meat. Cases of local control of cutworms by birds must be of frequent occurrence. However, only the following cases seem to be on record: Three instances relating to unidentified cutworms—namely, control of ground cutworms in Massachusetts by starlings, and in Utah by meadowlarks, and of climbing cutworms in California by crows—and the following relating to identified forms. Prof. J. R.

[23] Am. Nat. I, No. 2, April, 1867, p. 89.
[24] Rep. Dominion Ent., 1917, p. 8.
[25] Proc. Ent. Soc. Nova Scotia, 1918, pp. 10–14.

Parker and associates found wild birds to be the most beneficial check upon the pale western cutworm (*Porosagrotis orthogonia*) in Montana. In Texas the boat-tailed grackle, locally called jackdaw, has several times been observed to clean up infestations of the cabbage looper (*Autographa brassicae*). The fall army worm has been extirpated from a peanut field in Florida by blackbirds, and from a millet field in Georgia by English sparrows. There are recorded instances of control of the common army worm in Canada and New York, and of local extirpation in Pennsylvania and Minnesota. Dr. Townend Glover reports that "a southern planter once stated to me that the cotton boll worm, which was destroying his cotton crop, had entirely disappeared after the visit of an immense flock of blackbirds, which, after devouring the worms, immediately left the neighborhood." [26]

The oak caterpillars (*Datana*) are large and conspicuously colored and have threatening actions, but all these characteristics combined do not prevent attacks by birds. In the District of Columbia, Mr. Robert Ridgway observed cuckoos feeding so persistently on a colony of *Datana integerrima* on black walnut that within a week it was absolutely exterminated. The destructive Zimmerman pine moth (*Pinipestis*) of the same family has serious bird enemies, and Mr. Josef Brunner reports that in the Rocky Mountain region the hairy woodpecker is unquestionably the most efficient natural force restraining the species.

Only a few species of birds have been observed feeding on the European corn borer, but among them the woodpeckers seem to do considerable good in some cases. Messrs. G. J. Spencer and H. G. Crawford, reporting on their studies in Ontario, state that "the downy and hairy woodpeckers have frequently been seen digging the borers out of the stalks and stubbles in the field. In one field these birds were computed to have taken 60 per cent of the borers." [27]

The tussock moth caterpillar is generally supposed to be too hairy for birds, but this is another strained assumption. When they are common in Washington, nearly every robin seen carrying food to its young shows a telltale white fluff at the end of its bill. Dr. J. M. Swaine and Mr. Alan G. Dustan report birds to be important enemies of the tussock moth in Canada, Mr. Dustan especially having made some interesting observations along this line. He found that birds and ants are responsible for holding the insect at par in forests. When he exposed larvæ to birds, the supply disappeared regularly and he credits birds with destroying half of the

[26] Rep. U. S. Commr. Agr. (1865) 1866, p. 42.
[27] Bull. 295, Ont. Dept. Agr., March, 1923, p. 7.

larvæ hatching in forests. He further says that "practically every egg mass laid above the snow line (and over 90 per cent of them are) had been either partially or wholly destroyed by birds."[28] Cases of local extermination of tussock moths are recorded for the English sparrows in Massachusetts and the hairy woodpecker in Ohio.

Even such obnoxiously hairy caterpillars as those of the brown-tail and gypsy moths are eaten by many birds and sometimes to an extent effective in control. Dr. L. O. Howard, chief, United States Bureau of Entomology, states that "Observations extending over a number of years show that birds are important in checking the spread of the brown-tail moth."[29] There has been reported to Mr. E. H. Forbush a case in which starlings had locally extirpated a mixed infestation of brown-tail and gypsy larvæ, and when Mr. Forbush was in charge of the gypsy-moth campaign for the State of Massachusetts birds were observed to so hold the gypsy moth in check at one locality for several years that work by the State force was suspended. In connection with this early work Dr. E. P. Felt was employed as entomologist, and he found it almost impossible to complete certain experiments with larvæ protected by netting bags because so many caterpillars were taken from the nets by birds. Sixty per cent of the gypsy-moth larvæ used in these experiments were destroyed by birds.

The insects of most economic importance in the next family to be taken up—namely, the Lasiocampidæ—are the tent caterpillars. These are conspicuous species and many observations have been made of their bird enemies. For the less common species known as the forest tent caterpillar (*Malacosoma disstria*) there are at hand 3 records of control and 1 of local extermination, and for the common tent caterpillar (*M. americana*), 6 of control and 9 of suppression. Entomologists contributing to these records include Misses Mary Treat and Caroline Soule, Prof. Clarence M. Weed, and Dr. John D. Tothill.

Among the Geometridæ or loopers, all smooth caterpillars, readily eaten by most birds, the larvæ of the linden-moth (*Ennomos subsignarius*) once a pest to shade trees, were so no longer after English sparrows had been introduced and became common. Dr. A. R. Grote and Dr. J. B. Smith cite cases of local extermination in New York and New Jersey, and Prof. Glenn W. Herrick says:

> The testimony regarding the activity of the English sparrow in exterminating this pest in cities seems to show rather conclusively that this much-disliked bird did actually bring about the destruction of this insect. Nearly every writer on the snow-white linden-moth makes acknowledgment to the

[28] Proc. Acadian Ent. Soc. 1922, p. 109.
[29] Farmers' Bull. 264, 1906, p. 18.

sparrow and declares that the cities owe their freedom from this insect to that bird.[30]

Cankerworms, also of the family Geometridæ, are a treat for most birds, and in special investigations of outbreaks it has been found that practically all birds of the infested region were feeding freely upon them. This has resulted in noticeable control, recorded in two cases, and in local suppression in five.

Cankerworms, as well as many of the other larvæ heretofore considered, are well exposed to birds and other enemies, but caterpillars that are concealed by no means escape, for example, larvæ of the leopard moth, which are very destructive to shade trees, but which in various localities have been noted to be held in check by native birds. "No other explanation," says Dr. W. E. Britton, "can be given of the scarcity of the leopard moth in the country, adjacent to infested towns, except the presence of insectivorous birds. * * * Mr. James Walker, of Newark, N. J., states 'that infested elms placed in a nursery outside of the city limits of Newark were rid of the larvæ by woodpeckers.'"[31]

Among the Tortricidæ the codling moth is the greatest pest, and almost every entomologist who has written on the subject substantially agrees with Prof. M. V. Slingerland that "by far the most effective aids to man in controlling the codling moth are the birds."[32] The two facts that have chiefly led to this conclusion are the great scarcity of intact hibernating cocoons and the abundance of empty ones which have evidently been rifled by birds. Long ago Messrs. Benjamin D. Walsh and C. V. Riley, noted entomological collaborators, said:[33]

> From the careful inspection of several large orchards in the early spring months, we are convinced that almost all of the cocoons of the apple-worm moth that have been constructed in the autumn on the trunks and limbs of apple trees are gutted of their living tenants by hungry birds long before the spring opens.

In Virginia, according to Mr. J. E. Buck, "counts of over 400 cocoons observed on apple trees revealed the fact that * * * birds had destroyed fully 85 per cent of the worms."[34]

From New Hampshire comes this report by Dr. E. D. Sanderson:[35]

> Only 5 to 20 per cent of the larvæ survived the winter. An examination of seven trees, which averaged over 38 cocoons per tree in the fall, showed but 5 per cent alive in the spring, 87 per cent having been killed by birds, 4 per cent by disease, and 3 per cent by cold. In another orchard 1,096 cocoons

[30] Cornell Univ. Exp. Sta. Bull. 286, p. 62, 1910.
[31] Ann. Rep. Conn. Agr. Exp. Sta. 1911, p. 329.
[32] Bull. 142, Cornell Agr. Exp. Sta., p. 41, 1898.
[33] American Entomology, I, p. 113, 1869.
[34] Ann. Rep. Va. Exp. Sta., p. 55, 1908.
[35] Agr. Exp. Sta. Bull. 143, pp. 64 and 82, 1909.

were examined in May, 1907, with 19 per cent alive, 66 per cent having been killed by birds, 6 per cent by disease, and 9 per cent by cold. It is quite evident that the birds, particularly the downy woodpeckers and the nuthatches, are the most important enemies of the codling moth in New England, and that they should be given every protection and attracted to the orchard in every way possible.

One instance is at hand also in which a California orchard apparently was freed of codling moths by red-shafted flickers.

In relation to other Tortricidæ, Prof. W. S. Regan has stated that blackbirds do much good by feeding on the fruit-tree leaf-roller in Montana,[36] and Mr. E. H. Forbush records the local suppression of a spruce moth in Maine by warblers.[37] The spruce budworm (*Tortrix fumiferana*), a prime pest of firs and spruce, also has very effective bird enemies. In times of great abundance of the insect in New Brunswick birds were observed to take over 13 per cent of the broods, and under more normal conditions in British Columbia more than 38 per cent.[38] "In this case," says Doctor Tothill, "the natural checks brought about a reduction of the insect before any trees were killed, and in the following year the outbreak subsided entirely, due to continued activity of the birds against the smaller number of larvæ."

The remaining families of Lepidoptera for which we have records of effective control by birds are the Yponomeutidæ and the Elachistidæ. One of the former group, the diamond-back moth (*Plutella maculipennis*) is a cabbage pest, and Mr. J. L. Harris, of Minnesota, testifies that this insect was entirely extirpated from his patch by blackbirds. In the Elachistidæ, a forest pest again, the larch casebearer (*Coleophora laricella*) has effective enemies among the birds. In fact, Mr. A. B. Baird says, of his New Brunswick observations, "Birds were among the chief factors in controlling this insect." The percentage of larvæ about clearings taken by birds was estimated at 75 per cent and for the area in general 25 per cent.[39]

HYMENOPTERA (ANTS, BEES, AND WASPS)

In this order ants attract attention by their combined destructiveness and abundance and thus afford opportunity for observations on control by birds similar to those here recorded for the other orders. Flickers often are observed to suppress small colonies of ants, and Mr. J. D. Mitchell and Dr. W. Dwight Pierce have recorded the destruction of an entire swarm of agricultural ants in Texas by jackdaws.[40] Another instance of bird control of Hymenoptera is

[36] Circ. 109, Mont. Agr. Exp. Sta., 1922, p. 12.
[37] Bull. 9, Mass. Dept. Agr., 1921, p. 44.
[38] Tothill, John D., Proc. Acadian Ent. Soc. 8 (1922) 1923, pp. 174–176.
[39] Proc. Acadian Ent. Soc. 8 (1922) 1923, pp. 169–170.
[40] Proc. Ent. Soc. Wash. 14, No. 2, June 1912, p. 72.

given by Mr. S. T. Kimball, of Ellington, Conn., who states that "The oriole has cleaned my currant bushes of the currant worm [41] for the past few years."

DISCUSSION

In the foregoing remarks are summarized 109 cases of control and 88 of local suppression of insects by birds. Neither of these figures is exact on account of the impossibility of reducing to numbers such expressions as: "Several times the birds were observed to clear up" certain infestations, or "many fields were kept clean," and the like. However, the exact number of recorded cases is a matter of little concern, as it can have no sort of close approach to the number that really occur. Consider, for instance, the cases of almost complete destruction of termite swarms by English sparrows that the writer has personally observed. These were three in number, and the locality of one was a telephone pole in an alley near the Bureau of Chemistry, of another a court of an apartment house on Park Road, where some porch timbers were the breeding place of termites, and of the third his own backyard in a suburb, where the lowermost riser of a flight of steps was the nursery of the white ants. Now, these are three widely separated spots in and near a city of considerable size; and the writer only by chance happened to be at each during the very brief period when it was possible to make the observation. In a city the size of Washington hundreds of such incidents must occur every season unobserved; in a thousand cities in the range of white ants, and in rural districts where the termites are subject to attack by numerous kinds of birds, there must be multiplied hundreds of cases. This, too, for only a single kind of insect; multiply again by the vast number of insects birds attack, over any one of which they may at times exercise local control, and it is evident that the number of cases occurring in the United States annually must run into the millions.

After this statement the reader may think that the author's enthusiasm as an ornithologist has overbalanced his judgment. To assure neutrality of opinion, therefore, let us leave the doings and sayings of ornithologists in abeyance and appeal to the entomologists again.

In writing about the migratory locust Dr. C. V. Riley, former Chief of the United States Bureau of Entomology, said:

> While little practically can be done by man to further the multiplication of the more minute enemies of the locust, much may be done to protect and to promote the multiplication of the larger animals, especially the birds. These

[41] *Pteronus ribesii.*

should be protected by most stringent laws, firmly carried out, restraining the wanton destruction too often indulged in by sportsmen and others.[42]

Dr. A. D. Hopkins, formerly in charge of Forest Insect Investigations, United States Bureau of Entomology, wrote in connection with his studies of insect enemies of the spruce:

I would recommend the encouragement and protection of all insectivorous birds, since they are undoubtedly of very great service in preserving a balance among the contending species of plant and animal life, and at times may render most valuable service in reducing the numbers of dangerous insect enemies.[43]

Dr. E. P. Felt, State Entomologist of New York, also dealing with forest insects, after noting the complete destruction by English sparrows of a flight of linden-moths, states:

Insect-feeding birds appear to be the most effective checks upon such outbreaks and occurrences such as noted above are additional arguments for the better protection of birds, since under present conditions, at least, the cost of artificial control in ordinary woodland areas would be prohibitive.[44]

Referring to the same insect pest Prof. Glenn W. Herrick, of Cornell University, remarks that "Undoubtedly one of the most efficient and feasible means for the control of this insect in our forests will be the better protection of our native birds.[45]

Mr. Arthur Gibson, entomologist of the Dominion of Canada, after detailing the usefulness of birds as enemies of the army worm concludes:

The value of protecting our native insectivorous birds will thus readily be seen, and farmers, gardeners, etc., should do all they possibly can to protect them.[46]

After calling attention to the value of birds as enemies of the tent caterpillars, Dr. J. M. Swaine, chief of the Division of Forest Insects, Canadian Department of Agriculture, puts in italics the assertion that "the protection and encouragement of our native birds would go far towards reducing the numbers of many injurious insects of orchards, shade trees, and forests."[47]

Prof. V. H. Lowe, entomologist at the New York State agricultural experiment station, says:

Every thoughtful farmer knows that among the most important forces he has to contend with, in his efforts to produce abundant crops, are the hordes of insects * * *. The birds are among his most useful allies in combating these enemies.[48]

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[42] U. S. Dept. Agr. Bull. 25, 1891, p. 34.

[43] Report on Investigations to Determine the Cause of Unhealthy Conditions of the Spruce and Pine from 1880–1893, Bull. 56, West Virginia Agr. Exp. Station, April, 1889, p. 269.

[44] 35th Rep. State Ent. N. Y. (1921), June, 1923, pp. 82 and 84.

[45] Bull. 286, Cornell Agr. Exp. Sta., Nov., 1910, p. 63.

[46] Bull. 9, Ent. Branch, Can. Dept. Agr., 1915, pp. 16–17.

[47] Ent. Circ. No. 1, Dominion Dept. Agr., 1913, p. 11.

[48] 58th Ann. Rept. N. Y. State Agr. Soc. (1898), 1899, p. 315.

Prof. C. M. Weed, formerly entomologist at both the Ohio and New Hampshire agricultural experiment stations, notes that:

> After many years of study * * * of the relations of birds to agriculture, we are convinced that the birds are a most potent factor in making crop production possible, that without them we should be overrun with pests—vertebrate and invertebrate—to an extent of which we now have no conception.[49]

Dr. Townend Glover, first entomologist of the United States Department of Agriculture, in one of his annual reports says:

> In short, it may be plainly stated that without the cooperation of certain birds, animals, etc., this country would be overrun with insect pests.[50]

And M. Leopold Trouvelot, distinguished French entomologist, whom I have quoted before in connection with bird enemies of the American silkworm, concluded from his observations that if the birds were killed off all vegetation would be destroyed by insects.

Thus it will be seen that the enthusiasm of entomologists relative to the usefulness of birds has reached the highest possible pitch, in some cases agreeing in substance with the celebrated dictum of Michelet, the French historian and essayist, that "Birds can live without man, but man can not live without the birds."

For a more reasoned statement of the utility of birds, let us quote Dr. S. A. Forbes, both an entomologist and ornithologist:

"Against the uprising of inordinate numbers of insects, commonly harmless but capable of becoming temporarily injurious," says Doctor Forbes, "The most valuable and reliable protection is undoubtedly afforded by those predacious birds and insects which eat a mixed food, so that in the absence or diminution of any one element of their food, their own numbers are not seriously affected. Resorting, then, to other food supplies, they are found ready, on occasion, for immediate and overwhelming attack against any threatening foe. Especially does the wonderful locomotive power of birds, enabling them to escape scarcity in one region which might otherwise decimate them, by simply passing to another more favorable one, without the loss of life, fit them, above all other animals and agencies, to arrest disorder at the start—to head off aspiring and destructive rebellion before it has had time fairly to make head." [51]

Hitherto we have considered chiefly the testimony of American observers but now let us give attention to Dr. H. Maxwell-Lefroy, the late dominion entomologist of India, since his opinion based on an extensive study of the food of birds in India, so closely parallels that of Doctor Forbes just cited.

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[49] Weed, C. M., and Dearborn, N., Birds in Their Relation to Man, 1903, p. 4.

[50] Rep. Commr. Agr., 1870 (1871), p. 31.

[51] On some Interactions of Organisms, Bull. Ill. State Laboratory of Natural History, Vol. I, No. 3, Nov., 1880, pp. 11–12.

"One has only to read the lists of the food of beneficial species of birds," says Dr. Lefroy, "to get an idea of the immense part they play in reducing insect damage. Nearly all insects have special enemies such as parasites which attack each individually, but which produce alternative abundance and scarcity of each insect; that is, with the natural action of the special checks such as parasites, you get alternative 'waves' of insect pest and parasite; this is where the birds' importance is shown; they are not restricted, they eat many kinds of insects and when a pest has for the time got ahead and is abundant, the birds are there to feed on it just because it is abundant, and because at one time, one is abundant, at another time, another is, and the birds eat them all. To put it figuratively they cut off the tops of the waves and tend to keep them all at a uniform level, none being ever destructively abundant. In my opinion from man's point of view this is the special function in nature of birds and if the bird population is small, outbreaks of insects are frequent." [52]

In other words, entomologists, ornithologists, all of us in fact may agree, without exaggerating the services of birds in the least, that we may look upon them as an ever-present force which automatically tends to check outbreaks, large or small, among the organisms available to them as food. It is a force that should be kept at maximum efficiency by protective measures and which should be taken into consideration and used whenever possible. At the same time we must not neglect to credit with their good services, and to protect and adapt to our ends so far as practicable, other insect-destroying vertebrates. Among these certain toads, lizards, shrews, and moles, may in their more restricted spheres, at times approach birds in individual efficiency, and bats may equal them. Various other mammals, reptiles, amphibians, and fishes also have value as insect foes which should not be overlooked. Let us prize them all according to their deserts, and utilize their services as best we may.

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[52] In Mason, C. W. The Food of Birds in India. Mem. Dept. Agr. India Ent. Ser. Vol. III, Jan., 1912, p. 364.

COLLARED SWIFT WITH YOUNG. SOME LIZARDS ARE HIGHLY INSECTIVOROUS

COMMON SKUNK (MOUNTED SPECIMEN). THE MOST EFFECTIVE INSECT DESTROYER AMONG OUR TERRESTRIAL MAMMALS

1. California Gull. The Gull That Saved the Mormons' Crop

2. A Flock of California Gulls Following a Harrow

MEADOWLARK. A GREAT FOE OF GRASSHOPPERS AND SIMILAR INSECTS. HAS CONTROLLED AN OUTBREAK OF THE COULEE CRICKET

RED-EYED VIREOS. THIS SPECIES HAS DESTROYED FROM 10 TO 90 PER CENT OF THE BROODS OF FALL WEBWORMS IN NOVA SCOTIA IN VARIOUS YEARS

THE CROW. A GREAT ENEMY OF WHITE GRUBS. IN SOME PLACES DESTROYS 90 PER CENT OF THOSE TURNED UP BY THE PLOW

THE FLICKER. ANTEATER, PAR EXCELLENCE. SOMETIMES EXTIRPATES ANT COLONIES

CARNIVOROUS BUTTERFLIES

By Austin H. Clark

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BUTTERFLIES IN GENERAL

No equally large group of insects in which the metamorphosis is complete show such a general uniformity of habit as do the butterflies. Both sexes of all kinds can fly, though in some the females are more sluggish and less proficient on the wing than males; in a very few the females are much more frequently seen flying than the males. All are day fliers. Most kinds fly only in bright sunlight, from the middle of the morning until mid afternoon, the females taking wing in numbers considerably later than the males. A number prefer the half light of wooded regions, and a few fly only in the early morning and again at dusk.

Nearly all caterpillars of butterflies are leaf eaters, living on dicotyledonous plants, and among these apparently preferring certain families. Some, of a special group, and a few others, feed on grasses. A very few, of a queer mothlike type, bore into pith and roots.

THE LYCÆNIDS

Only in a single group of butterflies does there occur a wide diversity of habits. This is the group embracing the hairstreaks, blues, and coppers called the Lycænidæ.

The Lycænidæ are far more abundant in the tropics of both hemispheres than in the temperate zones, but even in the latter, especially in Asia and Europe, they form a large proportion of the local species.

As stated by Trimen, the numerous species, though of small size, are, as a rule, remarkable for brilliancy of coloring and exquisite variegation of marking. Richness of hue is, however, usually confined to the upper surface of the wings, which in the males often presents one vivid field of metallic orange-red or glistening blue, while in the female it is usually duller, varied with spots, or more suffused with grayish or with blackish, and occasionally wholly brown, presenting a totally different aspect to that of the male. The underside, on the contrary, differs but very little in the two sexes; it is commonly of some soft shade of gray or brownish, marbled or streaked with transverse darker or paler lines, or with rows of white ringed spots, and is not infrequently ornamented with very brilliant metallic dots, usually on the hind wings. Mr. Scudder adds that the antennæ are almost always ringed with white, and a conspicuous rim of white scales encircles the eyes.

THE CATERPILLARS OF THE LYCÆNIDS

Lycænid larvæ are for the most part shaped like wood lice or sowbugs, and in many cases look more like a coccid or some vegetable excrescence than like a caterpillar. Their legs often are extremely

short, so that they resemble slugs in their gliding movement. Some of them are smooth, many are clothed with a short down, some have fascicles of short bristles or regularly disposed tubercles, and a few are hairy generally. Several are regularly corrugated dorsally, and others prominently humped in one or two places. Some are furnished with a hard flattened shield on the dorsal region of the last three segments which is used by them to plug up the holes in the fruits on the interior of which they live.

The majority of lycænid larvæ feed on the buds, flowers, and young leaves of dicotyledonous plants—trees, bushes, or low-growing herbs. A number feed on the seed pods of leguminous plants; these have very long necks, so that with their mouths they can reach far into the interior of the pods and thus scoop out the contents with the greater portion of the body remaining outside. The caterpillars of three oriental genera feed on the interior of fruits of several different kinds. The caterpillars of a special group (Lipteninæ) live on the bark of trees, sometimes on rocks, feeding on the lichens and the algæ growing there; one of this group, however, is a grass feeder (*Durbania*). Lastly the larvæ of all the species of two groups, so far as known, and a few others feed upon other insects.

BUTTERFLY CANNIBALS

Although the only truly carnivorous butterflies are found in the Lycænidæ, the caterpillars of many other types of butterflies are on occasion cannibals. This is particularly true of the vegetarian lycænids. Our common little blue (*Cyaniris ladon*) for instance, and certain of our hairstreaks are notorious in this respect. But the common black swallowtail (*Papilio polyxenes*), the blue swallowtail (*Laertias philenor*), the common milkweed butterfly (*Anosia plexippus*), and a few others are known also to be sometimes cannibals.

When a caterpillar is about to transform into the pupal state it becomes quite helpless; after the larval skin is shed and until the new skin of the pupa hardens it is more helpless still. It is at this time, just before and just after the transformation to a chrysalis, that a larva is most subject to attack by its companions.

LYCÆNID CATERPILLARS AND ANTS

In many lycænid larvæ there is a transverse oval opening on the dorsal line of the eleventh segment with lips like a little mouth. These lips can, at the will of the larva, be somewhat protruded and a drop of sweet liquid expelled. Ants of very many species are immensely fond of this sweet liquid, and in return for it act as most efficient guardians of the larvæ.

In India, Mr. de Nicéville has found as many as four species of ants attending one species of larva. Not only do the ants attend the larvæ from their very first stages until they are fully grown, but they often cause the larvæ to change to pupæ within their nests, sometimes taking them deep under ground, in this manner protecting them from the time they emerge from the egg to the hour they assume the perfect form and fly away. One ant even goes so far as to surround each separate caterpillar and the leaf on which it has been feeding with a few strands of its silken web, protecting it jealously and attacking most fiercely any living thing intruding upon it. In the case of the larvæ of a Ceylonese species (*Aphnæus lohita*) which frequent the nests of *Cremastogaster* on *Acacia* and *Grevillea* trees, on the foliage of which they feed, the caterpillars are herded in special shelters built by the ants and are driven out at night to feed and brought back home to their shelters in the morning. There are many other interesting types of association between lycænid caterpillars and various ants.

Mr. de Nicéville and others have remarked that ant-tended lycænid caterpillars are most easily found by looking for the ants. The caterpillars are usually colored like the leaves, buds, flowers, or seed pods upon which they feed, and are for other reasons not easy to detect; but the restless black, brown, or red ants are very conspicuous.

THE SIGNAL TOWERS OF LYCÆNID LARVÆ

On the twelfth segment, the next behind the one bearing the oval opening from which the honey is exuded, are two other organs, one on either side in the subdorsal region, each of which looks like a stigma, but is a little larger. From each of these the caterpillar can extrude at will a membranous cylinder or tall pillar with a crown of tentacles about the summit. Mr. W. H. Edwards has suggested that these curious organs when extruded serve as signals for the ants, inviting them to come and examine the mouthlike opening on the eleventh segment. It has been supposed, and with good reason, that from these processes an odor is given off attractive to the ants. They are at once withdrawn if an ant approaches, and the ants are never allowed to touch them.

THE WHIRLING BRUSHES OF *CURETIS* CATERPILLARS

In the oriental genus *Curetis*, which in the larval stage does not possess the mouthlike organ on the eleventh segment and is not attended and protected by the ants, these two organs are of very great size. Each organ consists of a tall "pillar" from which, when the larva is touched or frightened, is instantly protruded a long tentacle

furnished at its head with a brush of long particolored hairs as long as itself. These hairs open out into a rosette, and the tentacle is whirled around with immense rapidity, producing a most curious effect.

ANT RESISTANT LYCÆNID CATERPILLARS

The bark-feeding lycænid caterpillars are without the glands giving out a sweet secretion. They are hairy and look more like the young of moths than like those of butterflies. They frequent ant-infested trees, living in the midst of passing swarms of ants, protected by them, but avoided by them, and giving nothing in return for their protection.

"ELECTRIC" LYCÆNID CATERPILLARS

In Nigeria Mr. Charles O. Farquharson found two sorts of lycænid larvæ feeding on the flowers of the mistletoe (*Loranthus*) to be "electric."

He wrote that these larvæ are of very characteristic shape, rather molluscoid or limacoid than onisciform, though they are smooth except at the margin, which is minutely bristly, doubtless to protect the feet. The "carapace", besides, comes right down so that the feet are not visible. In section the larvæ are more or less triangular. The posterior part is bilobed, and in one of the species there are little lobes anteriorly. They have tubercles, exserted very rarely, but if they have a gland it is hard to see. They are not ant-attended. They are relatively large, so that it is possible to lift them between the finger and thumb toward the anterior end without the skin of the fingers coming in contact with the marginal fold.

In handling one of these Mr. Farquharson was conscious of a curious sensation in his finger and thumb, which he found difficult of description. As nearly as possible it reminded him a very faint electric shock, not accompanied by a prickly sensation, but rather as if one were tickled by a tiny bunch of slightly strong bristles. The sensation was not that of tickling so much as that of a faint shock which was not continuous but rapidly intermittent.

The skin of the larva is covered with yellow dots, very minute and scarcely visible to the unaided eye, like glandular dots on a leaf. Mr. Farquharson says that, so far as he can make out there is nothing on the larval epidermis that could scratch the hand. On putting the larva down there was no after sensation as there would be after stinging.

According to Mr. Farquharson *Tanuetheira timon* is the species with the most markedly "electric" caterpillars, but the larvæ of *Epamera farquharsoni* are slightly "electric" also.

Dr. Harry Eltringham believes that the sensation described by Mr. Farquharson as "electric" is due to the capability of producing when handled extremely rapid muscular contractions or vibrations by which the extremely rough cuticle of the caterpillar is made to grate upon the skin. He noted a "shivering" at short intervals in larvæ of *Thecla pruni* which in general appearance are not unlike these larvæ from the mistletoe.

STINGING LYCÆNID CATERPILLARS

Dr. Harry Eltringham found that in the larvæ of *Teratoneura isabellæ* there are on segments 5 to 8, inclusive, dorso-laterally placed dark patches which consist of masses of urticating spicules, a most remarkable feature in a butterfly caterpillar.

THE DISCOVERY OF CARNIVOROUS BUTTERFLIES

The first butterfly actually known to be carnivorous was the North American *Feniseca tarquinius*, originally described by Fabricius in 1793. Mr. John Abbot, an Englishman who lived for a number of years in Georgia, discovered the larva and pupa of this species a few years after it was first described and drew most excellent figures of them which are now in the British Museum. He said that the caterpillar is "covered with a white loose down," which is in reality the flocculent secretion of the aphids on which it feeds; but he never suspected that the caterpillar of a butterfly could be carnivorous. In various notes, published and unpublished, he gave a considerable list of supposed food plants.

Following Abbot's observations previous to 1800, the next item of interest was found by Mr. S. H. Scudder in the notebooks of Dr. Asa Fitch after the latter's death. In an entry dated January 7, 1855, he wrote "I wholly forget the history of these specimens; I find the pupæ slightly attached to the sides of a pill box, and the butterflies hatched therefrom, and in the same box some beech leaves and woolly plant lice (*Schizoneura imbricator* Fb.). I conjecture the worm from which the pupæ came must have been feeding among these lice, but have no recollection of the fact." The butterflies were *Feniseca tarquinius*, and this was the first suspicion of the occurrence of a carnivorous habit in a butterfly.

As related by Mr. Scudder the earliest observation of the direct association of the caterpillar of this species with the plant lice was made by Misses Soule and Eliot late in July or early in August, 1880, when summering at Stowe, Vt. They brought into the house a branch of alder white with aphids. "It was left in a corner for a day or two, and meanwhile small, greenish caterpillars appeared about the room, on the walls and bureau. They pupated on the walls, the mop board, the pincushion, and the sides of the bureau.

The chrysalids were shaped like the ace of clubs." When they emerged the butterflies were identified. "The next year we found one larva on an aphis-covered alder, but have never seen one since."

On July 8, 1880, Mr. Th. Pergande found the caterpillars in the leaf curls of *Pemphigus fraxinifolii* on ash and found that these died without feeding on the leaves that were placed with them. In 1881 search was again made for the caterpillars on the same tree without finding any.

On August 23, 1882, three caterpillars were found on a twig of witch-hazel; they were not feeding when seen, and attempts to feed them upon leaves with which they were placed in a jar failed; the caterpillars died.

On October 2, 1882, several caterpillars were noticed with *Schizoneura tessellata*. They were intermixed with the aphids and not readily observed, but seemed to hide among the mass of plant lice. They were brought home with some of the aphids for experiment; and while the caterpillars were actively crawling about for some days, they all died without its being noticed that they fed upon the aphids.

On September 18, 1884, again a few caterpillars were found among the same *Schizoneura*. They were placed in a jar with the branch containing some of the plant lice. Subsequently they were found crawling about, and the aphids had disappeared, some of them having apparently been eaten. This gave rise to a conviction that the butterfly larvæ fed upon the lice, but they all died without the fact being proven.

On August 8, 1885, the larvæ were again found of all sizes among *Pemphigus imbricator*. They were quite active, crawling over the plant lice, and stopped as soon as the twig was touched. The egg-shells were at the same time observed, and the actual fact of feeding on the lice was proved by direct observation. On August 12 several had changed to pupæ, and by August 20 four adult *Feniseca tarquinius* had emerged.

On February 20, 1886, Prof. C. V. Riley read a paper before the Biological Society of Washington on "A carnivorous butterfly larva," which was published in Science on April 30, 1886, and again in the American Naturalist in June of the same year. In this he mentioned the work of Mr. Pergande and stated that he had obtained abundant evidence that the larvæ of *Feniseca* actually feed upon the aphids of the beech and alder. He also said that Mr. Otto Lugger had frequently observed the larvæ around Baltimore among *Pemphigus imbricator* on the beech, but never dissociated from the lice, and that Judge Lawrence Johnson also found it in connection with the same species around Shreveport, La., in the autumn of 1886 and

surmised that it might feed upon *Pemphigus*, but neither of these observers was able to get positive proof of the fact.

On October 29, 1886, Mr. W. H. Edwards published a detailed account of the life history of this species, based mainly upon observations by Miss Emily L. Morton, of New Windsor, Orange County, N. Y.

Certain corrections in regard to Mr. Edwards's historical remarks and Mr. Pergande's notes were published by Prof. Riley on December 29, 1886. On this same date Mr. George Haley, of Brownfield, Me., published his observations on this butterfly. He had noticed it alighting on a species of aphid, *Schizoneura tessellata*, found in crowds on the bark of alder, and from the position of its abdomen it seemed to be going to lay an egg among the plant lice; but seeing him, did not. Afterwards he scraped some of these aphids off a twig of alder and found a couple of larvæ. These he sent to Mr. Edwards, who said they were *Feniseca tarquinius*, as he had thought. On another occasion he found two full-grown larvæ among the plant lice, one of which changed to a pupa. On sending the caterpillars to Mr. Edwards, Mr. Haley said he thought they fed on the plant lice, as there were many dead bodies or skins of the lice where he found them. Later he saw in the American Naturalist that the larvæ probably fed on this species of aphid, and also on *Pemphigus fraxinifolii* found on the twigs of beech trees.

Dr. W. J. Holland in April, 1887, having read Mr. Edwards's account of the carnivorous habits of *Feniseca tarquinius*, suggested that *Liphyra brassolis*, an oriental butterfly, was similarly carnivorous. He had received from the Rev. L. C. Biggs a parcel of insects collected by Mr. F. J. Durnford in Sungei-Ujong. Mr. Biggs in his notes called attention to a particular specimen, saying: "It looks as if it were covered with mildew, which Durnford assures me is really fluff detached at the time of its capture." Among the envelopes containing insects Mr. Holland found several with specimens of a large "mealy-bug." The true explanation of the "fluff" or mealy deposit upon the abdomen and lower side of the wings of the butterfly, which was an example of *Liphyra brassolis*, instantly flashed upon his mind. He hastily looked up the envelopes containing the scale insects or "mealy-bugs." A comparison beneath the microscope of the white particles clinging to the abdomen and lodged upon the wings of the *Liphyra* with the mealy covering of the shield-lice preserved in the envelopes revealed their identity, and he therefore concluded that the white fluff on the butterfly was acquired while ovipositing on scale insects.

The white "fluff" on the *Liphyra* was undoubtedly a part of the fugitive fluffy covering with which on emergence this butterfly is

abundantly supplied instead of "mealy-bug" secretion; but nevertheless Mr. Holland was correct in his suspicion that *Liphyra* is carnivorous.

The second butterfly actually known from observation to be carnivorous was the Indian *Spalgis epius*. Writing in 1890, Mr. Lionel de Nicéville recorded that Mr. E. Ernest Green sent him drawings of the larva and pupa of this species from Pundul-oya, Ceylon, and said: "I have several times reared an insect indistinguishable from *S. epius* from a carnivorous larva that associates with and feeds upon *Dactylopius adonidum* (the 'mealy-bug' of planters)."

In January, 1892, Dr. W. J. Holland published an extract from a letter from the Rev. Dr. A. C. Good dated January 19, 1891, in which the latter noted that he had found the larvæ of a butterfly which had been described as *Spalgis s-signata* by Doctor Holland in November, 1891 (=*S. lemolea* H. H. Druce), and that he thought the caterpillars must have fed on plant lice.

In this paper Doctor Holland listed four lycænids the caterpillars of which are characterized by carnivorous propensities; these were:

Feniseca tarquinius.	*Spalgis lemolea.*
Spalgis epius.	*Liphyra brassolis.*

He said further: "I strongly suspect that the larvæ of *Lachnocnema* and of *Euliphyra*, mihi, are like the larvæ of *Spalgis* and *Feniseca* in their food habit."

In September, 1894, Mr. E. H. Aitken published extended notes on the young stages of *Spalgis epius*.

Mr. F. P. Dodd in 1902 published a detailed account of the development of the remarkable *Liphyra brassolis* which lives in the nests of tree ants, feeding on their young.

In 1903 Mr. F. W. Frohawk remarked that from observations he had made in the year preceding he felt convinced that some connection existed between the larvæ of the large blue of England (*Lycæna arion*) and the common yellow ant (*Formica flava*) because of the preference shown by the butterfly in selecting for the deposition of its eggs thyme plants growing on ant nests. He suspected that these larvæ might feed in their later stages either on the larvæ or the pupæ of the ants, since after the third molt they persistently refuse to remain on the plants and appear to have a tendency to hide in the ground. In 1905 Mr. Frohawk, in company with Mr. A. L. Rayward, found the pupa of this species, and in the following year these two gentlemen dug the full-grown larvæ out of ants' nests.

Mr. John C. W. Kershaw in 1905 described in detail the carnivorous habits of the caterpillars of *Gerydus chinensis*.

It is to Mr. W. A. Lamborn that we owe the bulk of our information regarding the curious and varied habits of different carnivorous butterflies. As a result of studies in Southern Nigeria he published in 1913 a most remarkable series of detailed and careful observations on no less than six different types. For the first time he described the larval habits of *Euliphyra mirifica*, *Aslauga vininga*, *A. lamborni*, *Megalopalpus zymna*, and *Lachnocnema bibulus* (of which the first and last had been suspected by Dr. Holland of being carnivorous), and he added much to the knowledge of the early stages of *Spalgis lemolea*.

In 1915 Dr. T. A. Chapman made the interesting observation that the caterpillars of *Lycæna arion* when in the last stage feed upon the full-grown grubs of ants. In 1918 he published a note showing that the larvæ of *Lycæna alcon* in their last stage feed on ant larvæ, like those of *L. arion*, but by sucking their blood instead of by devouring them.

In an interesting series of observations on the lycænids of Southern Nigeria published in full in 1921, Mr. Charles O. Farquharson added *Triclema lamias* to the list of species known to have carnivorous young, and gave further observations on the young of *Lachnocnema bibulus*.

THE CARNIVOROUS BUTTERFLIES

Of the eight subfamilies included in the family Lycænidæ two, the Gerydinæ and Liphyrinæ, so far as known, contain only carnivorous species. There are several additional carnivorous forms, some of which are peculiar in having the caterpillars carnivorous only in the last stage, in another subfamily, the Lycæninæ.

The subfamily Gerydinæ includes the genera *Gerydus*, *Parageryd*us, *Allotinus*, *Megalopalpus*, and *Logania*, of which the young are known only in *Gerydus* and in *Megalopalpus;* but suspicious actions have been observed on the part of the adults of *Allotinus* which resemble similar actions of the adults of the closely related *Megalopalpus*.

The Gerydinæ are distinguished from the other lycænids most conspicuously by their curious legs, which are sometimes very long; the tibiæ or tarsi are elongated or otherwise peculiar. The included species are all dull little butterflies, wholly, mostly, or largely black or dark brown above, with markings of bright brown, ochreous, or white, rarely violaceous. The males have no secondary sexual characters and usually do not differ in color from the females. They have a strong irregular mothlike flight, dancing about a favored

locality or flying back and forth along a path, and are very loth to leave any particular spot. Some, like *Gerydus chinensis*, seem to become more active toward evening, but others fly only in the middle of the day, and only on sunny days. Colonel Bingham writes that in India the habits of the members of this subfamily are alike. The females, at any rate of *Gerydus* and *Allotinus*, which he has closely observed in life, flutter about among low bushes and the undergrowth at the edges of the forest. The males, on the contrary, sit erect on the upper side of the leaves at the extremity of some branch of a tree at no great height above the ground, and from these points of vantage make short, sharp, circling flights, returning to the same or a neighboring leaf and invariably sitting with their heads turned toward the open and not toward the tree.

The subfamily Liphyrinæ includes the genera *Liphyra*, *Euliphyra*, and *Aslauga*, containing the largest and stoutest species of Lycænidæ. As in the Gerydinæ the species are largely black or dark brown above with brown or white markings, and some, at least, fly toward evening. The butterflies of this subfamily seem to be related to those of the Curetinæ, though the caterpillars of the latter are all plant feeders.

In the very large and heterogeneous subfamily Lycæninæ, which includes all our blues and coppers, the genera *Spalgis*, *Feniseca*, and *Lachnocnema* contain only carnivorous species, while species of *Lycæna* and of *Triclema* are at first plant feeders, becoming carnivorous in the later stages.

The butterflies actually known to have carnivorous caterpillars are the following:

Subfamily Gerydinæ.
Gerydus chinensis.
Megalopalpus zymna.
Subfamily Liphyrinæ.
Liphyra brassolis.
Euliphyra mirifica.
Aslauga vininga.
Aslauga lamborni.
Subfamily Lycæninæ.
Lycæna arion.
Lycæna alcon.
Spalgis epius.
Spalgis lemolea.
Feniseca tarquinius.
Lachnocnema bibulus.
Triclema lamias.

CARNIVOROUS BUTTERFLIES FEEDING ON THE SECRETIONS OF OTHER INSECTS

Mr. W. A. Lamborn found a female *Megalopalpus zymna* on the same stem with a membracid (*Leptocentrus altifrons*) and four attendant ants. The butterfly was probing with its proboscis under and around the membracid, and he was quite sure that the proboscis occasionally touched the insect's body.

On another occasion Mr. Lamborn took a male and a female which were probing with their tongues under and around a mem-

bracid (*Anchon relatum*) near which were two immature and one mature jassid (*Nehela ornata*), which apparently were also probed by the butterflies. Two specimens, one a male, the sex of the other not given, were obtained which were sucking food from the fore wing of one or other of two membracids (*Leptocentrus altifrons*), which were on a green stem side by side and were attended by 19 ants. Another male was taken sucking food off the fore wings of 3 jassids (*Nehela ornata*); 9 ants were in attendance. A female was taken on a green stem probing with its tongue and evidently sucking up food material from 3 jassids (*Nehela ornata*), which were attended by 5 ants. A male was captured probing with its proboscis a larva of a membracid (probably *Gargara variegata*, eaten by its own larva); 17 ants were in attendance.

Mr. Lamborn saw a worn *Megalopalpus* feeding on a fresh leafless shoot covered with sticky secretion which ants also were enjoying. On the next day he saw the same individual in the same position, so, with a view to subsequent identification, he trimmed its right hind wing off square with a pair of scissors. When released it flew into a shrub near by, but on the following morning it had returned and was again feeding. He saw it again on the twig the next day, and four days after he first saw it, in the early evening, he took it in his fingers and put it in the killing bottle.

Mr. John C. W. Kershaw found that the female of *Gerydus chinensis* in order to oviposit alights in the midst of aphids and ants which she thrusts aside with a brushing movement of her tail. Both male and female are very found of exuding sap, and half a dozen may occasionally be seen close together on a leaf or stem thrusting their tongues into any interstices left by the aphids. The ants do not appear to meddle either with the butterflies or with the eggs. It seems in this case most probable that what the butterflies are searching for is not plant sap but honey drippings from the aphids. Before the relationship between the two was known, Mr. Emery wrote that *Feniseca tarquinius* alights upon the woolly plant lice of the alder and with the ants enjoys the copious exceedingly sweet liquid exuded from their bodies.

BUTTERFLIES WITH HABITS SUGGESTING CARNIVOROUS PROPENSITIES

Gerydus symethus.—Mr. Distant wrote that it has been erroneously stated that this species inhabits ants' nests, but that no real facts can be adduced in support of the assertion.

Mr. de Nicéville suggested it may be that ants carry the full-grown larvæ into their nests to perform their transformations as in the case of *Tarucus theophrastus* and other species (for instance *Catochrysops phasma* as reported by Mr. Farquharson); but that

the adults inhabit the nests altogether as has been stated is almost certainly incorrect.

It seems a reasonable assumption that, if the caterpillars of this species have the habits of the allied *G. chinensis*, they may sometimes be inadvertently entombed in shelters built by ants about colonies of aphids, in which event the adults would be found therein imprisoned.

Allotinus horsfieldi.—Lieut. Col. C. T. Bingham in 1907 published a communication from Col. H. J. W. Barrow, who wrote: "I don't know whether you have observed the habits of a small plain butterfly which I caught in Maymyo. I watched it often in the jungle, sometimes for an hour at a time. It puzzled me at first to know why it took such an immense time to settle. It would keep within 1 yard of a spot and almost settle, 20 times, perhaps, before it actually did. Its legs are immensely long, and I discovered why. It settles over a mass of aphides and then tickles them with its proboscis, just as ants do with their antennæ, and seems to feed on their exudations * * *. It would settle calmly over largish ants and did not mind one or two actually standing up and examining its legs to see who was there. The ants did not attack it in any way."

Allotinus nivalis.—In 1910 Mr. Hamilton H. C. Druce published a note communicated by Mr. J. C. Moulton on a lycænid in attendance on an homopteron.

Mr. Moulton showed Colonel Bingham's figure of *Allotinus horsfieldi* attending an aphid to his two Dyak museum collectors, telling them to look for an example of this in real life when collecting in the jungle. He further explained that the species figured is a common one in Sarawak and that there was no reason why they should not be able to observe this phenomenon if they waited and watched the insect settle. For a month they were unsuccessful, although collecting four or five days a week. At last, on December 31, 1909, one of the collectors, Rigi by name, came back triumphant with two examples of *Allotinus nivalis* (a smaller species than *A. horsfieldi* but nearly allied) together with an homopteron. He told Mr. Moulton that he had found the two butterflies hanging downward from the underside of a thin twig of a "kapa" tree about 2 inches apart and facing toward each other; between them were two homopterons, and each butterfly was engaged in slowly stroking the homopteron nearest it with its tongue. The antennæ were in an upright position as shown in Colonel Bingham's illustration.

Mr. Moulton remarked that in Colonel Bingham's picture the aphid is shown as firmly held between the fore legs of the butterfly as if the "milking" operation were not particularly voluntary on the part of the aphid. But his Dyak was quite positive that the

fore legs were not used for this purpose at all in the instance he witnessed, and that the homopteron was quite free. There were plenty of ants on the branch, which was some 4 to 5 feet from the ground, but they did not seem to disturb the butterflies.

About January 20, 1910, the same native again brought in this species of *Allotinus*, together with an homopteron, telling Mr. Moulton that he had watched them for a long time and that he was convinced that the lycænid in no way held the homopteron. On February 2, 1910, he brought in another *Allotinus* (of a species near *nivalis*) which he had found in similar attendance on the same species of homopteron (also brought in). As before, he told him that he watched them for some time to see if there was any restraint imposed on the homopteron, but he was quite sure that it was free.

About February 10, 1910, Mr. Moulton's Dyak Rigi brought him an example of *Allotinus horsfieldi* which he had taken in attendance on a "heteropterous larva." In the case of this last observation the collector reported having noticed large numbers of this insect on the tree in company with many ants, which latter appeared to be bothering the lycænid, although he stuck to his work in spite of the ants until the collector's net removed him. In the previous observations, except for the homopterons attended by the butterflies, none or but few were seen on the same tree.

Gerydinæ, sp. indet.—In a letter to Prof. E. P. Poulton, Mr. J. C. Moulton wrote:

> I watched some few months ago a group of ants, a Lycænid belonging to the subfamily Gerydinæ, and Homoptera (identified by Distant as the Membracid *Ebhul varius* Walker, previously only known from the unique Burmese type). The Membracids were quite passive while ants vigorously massaged them and imbibed the exuding liquid. The *Gerydus* rested within a foot of an ant slowly stroking an Homopteron with his proboscis and I suppose at the same time drawing up liquid.

According to Professor Poulton the observation was made in the neighborhood of Kuching in 1913.

These observations by Colonel Barrow, the Dyak Rigi, and Mr. J. C. Moulton must be considered in connection with Mr. Lamborn's notes on *Megalopalpus*, the African representative of the oriental *Allotinus*, and Mr. Kershaw's on *Gerydus chinensis*. *Feniseca tarquinius* also seems to be quite immune from attack by ants.

A NONCARNIVOROUS BUTTERFLY FEEDING WITH IMPUNITY AMONG ANTS ON COCCID SECRETIONS

Mr. Charles O. Farquharson gives an excellent account of a butterfly of the genus *Teratoneura* feeding on the secretions of ant-attended coccids and driving off the ants.

He noticed the insect alight on a twig. It remained for a few seconds and then flew off, circling rapidly round the stump, soon to alight again. It lit on a branch with ants and coccids on it, just at the tip, the coccids being about an inch from the end. It proceeded to walk backwards rather slowly and deliberately, the abdomen inclined upward at a fairly steep angle to the thorax, and the wings opening and closing fairly rapidly—though not by any means nervously or excitedly—and gently beating the twig. The ants retreated backwards, making hardly any resistance at all, though some dodged to the under side of the twig and ran forwards.

The butterfly having gone back about 3 inches, then suddenly dropped the abomen so that it rested on the twig and ran rapidly forward, the tip of the abdomen brushing the twig as it did so. The backward maneuver was repeated, this time on the underside of the twig, the wings then hanging downwards, the abdomen flexed as before. The butterfly suddenly stopped over the coccids, unrolled a very slender proboscis, and proceeded to absorb the secretion so very much prized by the ants.

Occasionally an ant would venture along, but retreated without attacking. In a short time the butterfly flew away, circled around for a bit, and came back to another twig, where the same performance was repeated.

Professor Poulton remarked that the movements described and the position of the abdomen of the butterfly suggest strongly that the butterfly produces and fans toward the ants some odor disliked by them.

Gerydus chinensis

Mr. John C. W. Kershaw has published an interesting account of the habits of *Gerydus chinensis* which he found to be fairly common throughout the year in certain localities near Macao and Hong Kong. Like *Feniseca tarquinius* it is local in its occurrence, keeping more or less strictly to shady and usually damp places. To a certain extent it is crepuscular, though it is also on the wing during the day.

When ovipositing the female butterfly, after almost interminable dancing up and down and wandering hither and thither, finally alights, after two or three attempts, in the midst of the aphids and ants, which she thrusts aside with a brushing movement of her abdomen, and immediately lays a single egg. She then generally moves slightly and remains for some time sucking up the exuding juices of the plant.

The eggs are laid toward evening and until night fairly sets in, on stems and leaves of herbs and trees infested with aphids or

Hemiptera. They are laid at intervals all through the year, but those mentioned by Mr. Kershaw were taken in July and August.

The plants the butterflies seem especially to affect are various species of bamboo, the lichee (*Stillingia sebifera*), and a species of burr marigold (*Bidens pilosa*), which last is very common in the region.

The aphids swarm so thickly that the plant stem or leaf is invisible and, barring heavy rain, they are, as a whole, stationary for days together, though slowly changing their position individually and going through various transformations, fresh lots continually replacing the old.

As in the case of *Feniseca tarquinius* the eggs of the butterfly are often hidden under a mass of aphids.

The egg is circular and flat, pale green in color, ringed circumferentially, the edges of the rings milled like a coin. It hatches in four days, the issuing larva being nearly cylindrical at first, not assuming its sluglike shape until a later stage. Its color is light yellow with a distinct purplish dorsal line and a few light-colored hairs chiefly at the head and tail. The head is dark. Later on the caterpillar becomes limaciform or sluglike, yellow or greenish-yellow, and banded longitudinally with purple brown. The segments are well defined, the first swollen and produced so that the head can be withdrawn entirely into it, as it usually is when the larva is resting.

The larvæ feed upon the aphids, sometimes pressing them against the plant with the head and forelegs, sometimes holding them in the fore legs quite away from the plant. A few bites disposes of an aphid, and the caterpillar then licks and cleans its legs just as a mantis does. Some aphids must have a better flavor than others, as the larvæ pick and choose, moving their heads up and down over the backs of the insects, evidently smelling them. As a rule the creatures seem to make little attempt to escape till they are actually bitten, when struggling is useless.

When not engaged in feeding the larvæ rest among the aphids or crawl leisurely about between or over them, and the aphids do likewise, the larvæ being sometimes covered with them.

When nearly full grown the larvæ lose most of their sparse hairs and their colors fade, the bands and four blotches on the seventh and eighth segments becoming less distinct.

The larval stage lasts about 15 days, and Mr. Kershaw reckoned that, on the average from first to last, the larvæ would eat some 20 aphids per day. But it would require many larvæ to make much impression on the crowds of aphids seen, perhaps a yard of bamboo 2 or 3 inches in diameter being absolutely covered with them.

Mr. Kershaw only found the larvæ feeding on two kinds of aphids, though he says they doubtless eat other kinds. One was slate-colored with a white efflorescence (as is the *Schizoneura* of the alder, the favorite food of *Feniseca tarquinius*), the other greenish with four dark-green patches, some of them being fringed with white, probably molted skins.

He was not sure, but had some reason for believing, that the larvæ tend to resemble in color the aphids upon which they happen to be feeding. At first, as the eggs had been laid amongst the green aphids, he fed the larvæ upon these; but, a typhoon having washed away the food supply, he could thereafter find only the slate-colored species which, however, the larvæ seemed quite as much to enjoy. But he noticed soon after that the colors faded, and the purple-brown tended to mingle with the yellow.

Mr. Kershaw says that one of the features of this curious life history is the calm way in which the caterpillar moves among the aphids and selects its prey, and the indifference with which the latter apparently accepts its fate.

When about to pupate the caterpillars walk about at quite a fair rate of speed and, having chosen a spot, spin a few threads a little distance from head and tail. Mr. Kershaw's larvæ pupated on a piece of bark, one putting a band about its middle and pupating horizontally, the other pupating vertically and without a band, though both had the threads (not attached to the pupa) at head and tail.

The tail of the pupa is cut off squarely, forming a disk, thus securing a good hold, probably sufficient without the band around the middle. It seems to be affixed with some secretion, not actual threads. There is a small process on either side of the third segment from the tail.

The pupal stage lasts about 10 days. As the larval stage lasts about 15 days and the eggs require 4 days to hatch the time occupied in the various transitions from the freshly laid egg to the emergence of the butterfly is about 29 days, or about a week longer than in the case of *Feniseca tarquinius*.

Both larvæ and pupæ struck Mr. Kershaw as small in comparison with the size of the butterfly.

Both the males and females of this butterfly, according to Mr. Kershaw, are very fond of the exuding juice of the plants upon which the larvæ live. Half a dozen may occasionally be seen close together on a leaf or stem drinking this sap, thrusting their tongues into any interstices left by the aphids.

It seems to me that what the butterflies are drinking is probably not the plant juice, but the exudations from the aphids which have fallen on the plants.

Mr. Kershaw noted that the plants upon which this species lays its eggs are overrun by a host of ants of two species (*Polyrrhachis dives* and *Dolichoderus bituberculatus*), both aphids and ants apparently feeding on juice exuding from the plants. Any vegetation subject to these secretions seems to be attractive to them, the ants not appearing to use the aphids as ant cows, though of this he was not quite certain.

The ants do not appear to meddle either with the butterflies or with their eggs, though ants are very destructive to the eggs of most butterflies; nor do they seem to interfere with the caterpillars.

In contrast to the immunity of this butterfly from the attacks of ants, Mr. Kershaw saw two small butterflies of other kinds (a skipper and a species of *Neptis*) seized by the tongue as they probed a flower and dragged off by one of the same species of ants among which the *Gerydus* live.

In 1914 Mr. Edward Step published a full page illustration of "A Butterfly Enemy of Green-fly" which was based upon the plate and the data in Mr. Kershaw's article, though the larvæ are shown upon bamboo instead of on *Bidens pilosa*.

Megalopalpus zymna

Mr. W. A. Lamborn worked out the life history of this species in the vicinity of Oni Camp, Southern Nigeria. Oni Camp is 70 miles east of Lagos, at a low elevation, never more than 50 feet above sea level.

The caterpillars of this butterfly feed not upon aphids, but upon a variety of Homoptera belonging to the families Jassidæ and Membracidæ which are invariably attended by ants.

The mother butterfly, in depositing her egg, which is a very characteristic one, exercises the same care in insuring an immediate food supply for the newly hatched larva as do other butterflies for their plant-eating offspring. She places it very commonly in the immediate neighborhood of an ant shelter containing Homoptera, and an egg shell is sometimes found attached to a stem actually within a shelter, having obviously been deposited before the Homoptera attracted the attention of ants, and, indeed, probably on the egg mass itself before hatching, since the membracid and jassid colonies seem to remain and feed close to the spot where the parent laid her eggs.

The egg masses of the jassids (*Nehela ornata*) are attached to plants in clusters much like those of the membracids (*Leptocentrus altifrons*); that is, in parallel rows often superposed so as to form oval masses. The lycænid larvæ do not interfere with these.

The eggs of *Megalopalpus* have been found attached to the egg mass of the Homoptera (the membracid *Leptocentrus altifrons*) and in two cases actually on living and half-grown membracid nymphs. Mr. Lamborn found two nymphs in the same colony of the membracid *Gargara variegata* unsheltered by ants each bearing an egg of *Megalopalpus*, in one case on the right side of the dorsal surface of the abdomen just behind the wing, and in the other on the base of the left wing.

The egg of the *Megalopalpus* is very characteristic, being a circular disk with a broad flattened white margin and a raised bluish semitransparent center.

The first larva found by Mr. Lamborn, brown in color and studded all over with tubercles, was discovered on a young leaf of an urticaceous plant (*Musanga smithii*). A number of small black ants (*Pheidole aurivillii* r. *kasaiensis*) were running about over the leaf on the under side and margins of which they had built up shelters of waste vegetable matter such as they construct so frequently over coccids. On cutting off the leaf with a view to making a closer examination, he shook it, with the result that several of the tiny insects left the shelters and jumped to a distance in all directions. He did not at the time attach any definite significance to the presence of these insects; but the larva would not feed in captivity.

Two days later he came across another cluster of ant-tended jassids of the same species on the stem of a different plant, and at rest close to them was a similar larva over which the ants were running. He then felt that the association must be more than accidental, so he cut the stem through and transferred it to a glass tube. Most of the jassids managed to evade capture by jumping off, but he secured three which soon gathered together again on the stem. By evening the ants were ministering to them with their antennæ; as he watched, the larva crawled slowly in the direction of the insects, stopping frequently and vibrating all three pairs of true legs. It stopped when it had nearly reached the jassids, and then again moved on with, he believes, only the first pair of legs in vibration. It then reached the insects and caused its vibrating legs to play on the closed wings of a jassid in such a way as to simulate, as he thought, the caresses of ants. Still advancing, it gradually raised the fore part of its body so as to overhang the insect and, when well above, suddenly dropped and seized its prey with all its true legs, immediately biting in behind the head, holding the insect pressed down on the stem; and when it had taken several mouthfuls, it raised the fore part of its body and continued feeding, now holding the jassid well away from the stem. The victim was by this time incapable of movement, and as the larva

had no difficulty in retaining it by means of its second and third pairs of legs, the first pair was used to take up loose fragments and guide them to the mouth. He saw a loose leg thus taken up and eaten, and in this way every particle of the unfortunate little "hopper" was secured.

After the meal the legs of the first pair were drawn one after the other between the mandibles and then polished on the outer side of the face, after the manner of a cat.

He continued to watch the larva closely. It remained without movement for about 20 minutes and then approached another jassid. This one was evidently not satisfied as to the honesty of its purpose, for immediately the larva commenced to tickle it the jassid ran away up the stem to a distance of about half an inch. However, the larva followed on and overtook it, and in due course it shared the fate of its predecessor, the series of actions by the larva being precisely the same as described in the former case.

On the following day he brought in more of the food insects, and the larva first found made up for its long fast by catching 9 out of 11 between 8 a. m. and 3 p. m.

The procedure was so interesting to him that he actually witnessed the caressing, capture, and eating of most of these, and he has seen it many times since. The caterpillars eat both nymphs and imagos of the jassids, but seem to secure more of the former, for, though they are able to jump and run with surprising activity, quite as fast as an ordinary ant, the imagos sometimes escape by flying. When imagos are eaten the hard anterior wings are usually rejected.

Mr. Lamborn remarks that in nature the slow-moving lycænid larvæ must depend for their very existence on the fact that these insects are gregarious and if disturbed frequently reassemble at the same spot.

If the caterpillar is on a broad surface it raises itself anteriorly when grasping a victim, but when on a narrow surface it drags the insect off its support by simply bending to one side or the other.

The first two larvæ found by Mr. Lamborn were feeding on the jassid *Nehela ornata*, an active jumping insect which they lull to a false sense of security by simulating the attentions of ants. The third larva found would not eat the jassid which was eaten by the other two. It was found in an ant shelter on *Triumfetta cordifolia* which covered a large number of little green hopping creatures which proved to be immature membracids. Another larva was found in a shelter containing membracid larvæ (*Gargara variegata*). He saw this larva feeding on a large larva of the membracid type, though he did not actually witness the attack. The caterpillar ate the body and then part of the head but was unable to

finish the meal, for a tiny ant, which had been dragging persistently at the remaining morsel, managed to get it away.

When a new shelter containing *Pheidole rotundata* var. and membracid larvæ was put into a tube an ant immediately seized the *Megalopalpus* larva ventrally just behind the mandibles. This larva was not successfully reared.

Other caterpillars of the same species were found in other shelters on *Triumfetta*, and once two were found in a single shelter.

The larva is dark brown, a tint approximating very closely to the color of the débris out of which the ant shelters are constructed.

The food seems to range within certain limits; but though larvæ have been found eating both jassids and membracids, a larva accustomed to take jassids will refuse membracids and *vice versa*, and there is some evidence that a larva which habitually eats one form of membracid will refuse a closely allied species.

One larva found ate a species of membracid closely allied to *Gargara variegata*, although it refused that species. Another was found to feed upon *Leptocentrus altifrons*.

An ant shelter on *Triumfetta* often contains, in addition to immature examples of *Gargara*, young membracids of several other species, apparently belonging to the genera *Anchon* and *Beninia*. Imagines of the genera *Anchon*, *Beninia*, or *Gargara* are frequently found in the open on a stem close to an ant shelter and tended by ants from it. These shelters are constructed by two species of ants.

Not only does *Megalopalpus* feed in the larval state on the Homoptera, but the butterfly seems frequently to flourish also at their expense, probing them with its proboscis and obtaining food material direct from their surface as well as from the plant on which they happen to be resting. As this habit is as characteristic of males as of females it can not be interpreted as bearing any relation to oviposition.

Mr. Lamborn has not found that the ants derive any benefit from the presence of this larva, or that they are of service to it. There is, on the contrary, some evidence to show that their attitude toward it is distinctly one of hostility, in connection with which it is noteworthy that the larva is not of the smooth, soft, onisciform type characteristic of the Lycænidæ, but is protected by a hard skin studded with tubercles which are surmounted by coarse sparse hairs.

The ants in attendance on the jassids frequently run over these caterpillars and stroke them with their antennæ, but are not so attentive as they are to other lycænid larvæ. Mr. Lamborn was under the impression that the attitude of the small black house ants toward this caterpillar was distinctly hostile. Besides the one mentioned above another caterpillar was attacked by house ants, one of which fastened on to one of its legs so that it had to be removed.

Mr. Lamborn several times watched *Megalopalpus zymna* deposit a single egg among ants, which have subsequently investigated it with their antennæ, but have not interfered with it.

Liphyra brassolis

Mr. F. P. Dodd, of Townsville, Queensland, published in June, 1902, an interesting account of this remarkable butterfly.

He had noticed a female on a warm sunny day in July, 1900, depositing eggs upon a tree which was in complete possession of the green tree ant (*Œcophylla smaragdina*). Upon this tree there were several large nests of the ants, and the butterfly would rapidly fly over the top of the tree once or twice, then come underneath and settle on one of the branches near the trunk. There were four spots to which it returned at different times after its flights, and on examination he found that there were two or three eggs deposited on each. Judging from the number of flights he believed that only one egg was laid at each rest. He has since frequently seen the eggs on other trees in ones, twos, or more; but deposits of two, in several different places, is the number usually to be met with. The eggs are placed on the under side of branches, or on the protected side of the trunk.

He took several of the eggs, and in 22 days the larvæ, flat oval creatures, appeared, but refused to eat, and died. He had taken them on the chance of their being leaf eaters, and with the ants merely for protection, as he had found is the case with several other Australian lycænids—*Arhopalas* and *Hypolycæna phorbas*.

Some weeks later he pulled the habitations of the ants to pieces, but could find no traces of larvæ from the ova left untouched and was unsuccessful with many other nests examined.

During the next few months he examined scores of nests in the hopes of finding the caterpillars of this butterfly, but without success. However, he eventually stumbled across a caterpillar when searching an ants' nest for other insects.

This individual was half grown, the size and shape being about that of a medium-sized lozenge, with a rim, as in a coin, bordering it all around, but raised somewhat along the dorsal surface. The color was a very pale yellowish brown with seven dark spots on each side near the margin. Across the center of the dorsal surface there were three furrows reaching nearly to the sides. These furrows are constant through all the molts (he notes it must be borne in mind that he has not examined larvæ less than about one-third grown, those obtained from the eggs having been lost before he had noticed them particularly), nor do they disappear even when the larval skin becomes the outer pupal shell. The head, legs, and pro-

legs are in a groove the edges of which close down tightly all around; consequently they are seldom seen, except, of course, during progression, when the body is raised a little.

After this discovery he met with other larvæ, generally larger and of a darker brown, and finally obtained pupæ and bred out a series of the perfect insect.

Taking several larvæ and supplying them with ant grubs, he soon had the satisfaction of observing one individual approach a half-grown grub, deliberately seize it, and withdraw it from sight; but, being impatient, he turned it over soon after, and it slowly released its hold of the grub. Unfortunately he failed to observe anything of the kind again.

Finding that the caterpillars did not thrive upon ant larvæ alone, they were supplied with small nests containing ants and pupæ as well, but in a week or so they showed signs of sickness. By changing the ant nests he kept several other caterpillars for nearly two weeks. They also became sickly and had to be returned to nests on the trees. However, they deposited frass, showing that they had been feeding; this is small for such bulky creatures, is gray or grayish white, and is greasy looking. So, though he could not positively declare that they exist upon the ant larvæ, he was quite satisfied himself that they do.

As five or even six caterpillars may be found in one nest, the quantity of food required by such large creatures must be considerable, though they are very slow growing; but the masses of ant larvæ could be drawn upon without making any great reduction in them.

He mentioned that he had at hand young caterpillars of a moth that feeds upon another species of ant living in the ground. When given the fresh grubs they soon take a lively interest in them and affix themselves thereto, appearing to suck their victims. None of the grubs are eaten, but they are considerably smaller and much shriveled when finished with. The moth is even more greasy than the butterfly. None of the grubs given to *L. brassolis* were eaten, but some had the same shriveled appearance as those given to the moth larvæ.

When the caterpillars are about to cast their skins they spin a webbed footing nearly their whole length, to which they affix themselves rather firmly; but in many instances the ants secure them still more firmly to their position, the web reaching half way to, or even up to the rim. Whether this ant web is added with friendly intent or with a view to fastening down a larva to get rid of it if possible is a puzzling matter; but Mr. Dodd has not met with any dead larvæ so fastened. Pupæ are occasionally treated in a similar manner

without the escape of the butterflies being thereby prevented. The larger larvæ require three to four days after taking up their molting position to crawl out of their old skins, which become a little darker and finally split downwards under the front edge and right and left along the rim. The old skin retains its shape above and, being relieved of its occupant, regains its former color, so that, viewed casually, it is difficult to believe that it is an empty shell, so closely does it resemble a real larva.

In changing to the pupa the larval skin is not cast off, but changes its shape and becomes a comparatively strong outer covering. The insect shrinks away from this and becomes detached, so that it can be shaken like a nut in its shell. The true pupal skin is very thin and transparent and, provided, of course, the outer shell is opened, the color changes of the chrysalis can be observed plainly. After the larva has taken up its position for the transformation there is no change for 36 hours or so, the first being a narrowing of the thoracic portion with an increased thickness of the same. Upon examining the future pupa at this time underneath it will be noticed that the shell has closed in on each side enveloping the head and legs completely; no closing in upon the prolegs occurs. For some hours no further alteration takes place; then the remaining portion of the creature contracts, accompanied by a considerable rise in the dorsal surface, the pupal change, so far as can be ascertained from external observation, now being complete. For several days after the shell is liable to split at the outside edge or rim if care in handling it is not taken, the whole of the top being liable to split and come off like a lid, and the chrysalis, being particularly delicate and pulpy, may be killed.

The perfect insect emerges in from 21 to 25 days, and further astonishing developments in the life history of this strange insect occur. Before bursting the outer shell the butterfly can be heard moving within, and shortly a sharp, cracking sound announces that the burst has been effected. Then either a portion of the shell, which opens in the center in front up to the first furrow, is broken right out or it opens sufficiently above after breaking away at the rim to admit of the imago's emergence.

Instead of the weak drooping wings of a butterfly the creature that emerges has little short appendages like those of a freshly emerged moth, and lying very flat; the front wing is creamy white to the extreme tip, and the edge of the hind wing projects from under this ever so little. The abdomen looks very large, a thick mass of furry looking substance showing on each side of it to the tip. On the thorax small tufts of loose, brownish scales may be noted which easily roll off.

It is soon seen that the white appearance of the fore wing is caused by a dense covering of fugitive scales; there is also a small patch of these on either side of the thorax. As the wings slowly lengthen the density of the scales lessens sufficiently to admit a view of the black and rich yellow coloring underneath.

After the expansion of the wings these white scales fly off at the least breath of air. A stroke or two of the insect's wing detaches every one in a cloud; thus it is a difficult matter to kill and set specimens and leave a fair proportion of these scales.

The matter on the abdomen is, of course, also composed of scales. They are dark gray, packed very densely, and cover about half the ventral surface, reach farther along the sides, but do not reach the thorax, none being on the upper surface. These are much more adhesive, and must be scraped away as they can not be blown off; they come away in masses and fasten lightly to anything they come in contact with; they appear to be held together. Upon examining them with a lens exceedingly delicate threads can be discerned dispersed throughout.

The legs and antennæ are also clothed with minute and easily detachable white scales.

The insect requires longer than the largest Australian moths to pump its wings to their full length. Mr. Dodd notes that it takes from 25 to 30 minutes, and instead of being prepared for flight in a little over an hour, like many large moths, is quite helpless for a much longer period, and none of Mr. Dodd's examples exhibited the least desire to fly in three or even four hours.

The butterflies are very oily, A thick layer of almost liquid grease lines the abdomen, so that in setting them Mr. Dodd found it necessary to resort to stuffing. Unfortunately, this operation causes displacement of the extra scales to some extent, especially in the males.

As to the butterfly being crepuscular in its habits, Mr. Dodd mentions that he is frequently out in the twilight, but has not met with it, though that may be on account of its rarity. However, it is decidedly wide awake in the daytime. Mr. Dodd captured several which he had disturbed as any ordinary butterfly would be disturbed. Several times they have flown from near ant nests which he was about to examine. One specimen was seen flying across an open space in the early afternoon, and had evidently come from a fair distance as there were no ant nests in the vicinity. Many years ago he caught his first specimen, a female, on a hot summer day at about 11 o'clock. It flew rapidly across a scrub and settled on a branch under the foliage precisely as the egg-depositing female did which he observed in July, 1900.

Concerning the loose scales on this unique butterfly Mr. Dodd says we have no evidence that the larvæ are welcome inhabitants of the ants' nests. However, it is highly probable that the ants have no friendly feeling for the perfect insect, and would most likely attack and kill it during its long rest after emergence if it were not specially and wonderfully protected. So it will be seen that the loose scales act as a perfect protection; for directly the ants encounter these they are in trouble; they fasten on to their feet and impede their movements or, if their antennæ or mandibles come into contact with any part of the butterfly the scales adhere thereto, so that the ant is soon in a bad way and has quite enough to do in attempting to free itself of its encumbrances without taking any further interest in the butterfly, from which it retreats as well as possible. It is exceedingly ludicrous to observe the ants endeavoring to free themselves; their legs move awkwardly, and their mandibles are opened and closed in evident annoyance and perplexity, and they are much concerned at the state of their antennæ, for the obnoxious scales will not be shaken off. It is amusing to observe the dejected change in an ant after its first spar with *L. brassolis*, for it is such a pert, pugnacious fellow and perfectly willing to tackle anything that moves if in proximity to its pets or nest.

The small wings of the insect enable it to get through the nest entrance. The scales on the forewing are necessary to its safety while it is crawling out, for the ants might in some cases evade its legs and get onto the thorax. But if the scales there did not vanquish them, those on the forewings would. As the butterfly's abdomen becomes strong enough it raises the tip to touch the support where it is hanging. In that position it is invulnerable; hundreds of ants could not hurt it. As the forewings lengthen and touch there is no further need of the scales thereon. The wind doubtless dislodges the majority before the insect flies off, but the other scales would not wholly disappear for some time.

Mr. Dodd placed four larvæ on a nest where he knew there were none, and afterwards visited it and obtained from it two pupæ. On another small tree with several ant nests seven larvæ were placed, and going there some days later he found one chrysalis on the outside of a nest, one within, several attenuated larvæ wandering about the tree—the ants, having become familiar with them, taking no notice of them—and a dead larva on the ground. It would appear that the entrance to the nests was too small for the larger caterpillars to gain admittance. Once he saw a larva on the outside of a new nest, and he took a pupa on another. These were in localities where he had not interfered with the ants. These instances serve to show, according to Mr. Dodd, that the larvæ pass from one domicile to another, presumably when their food is exhausted in

one. They are very slow moving, and when they find it necessary to change quarters they must wander after sundown, for out of over 80 larvæ and pupæ that passed through Mr. Dodd's hands not a single example was parasitized.

The larvæ of *L. brassolis* are evidently so tough skinned that the mandibles of the ants can make little or no impression upon them, for in placing specimens upon a nest the inmates rush out at them, catch hold of the rim, and appear to be acting most viciously. They also endeavor to reach the head or legs, but these are at once protected; the creature just lowers its great sides and is secure. After examining caterpillars that had been on nests for several days, and tugged at and nipped by dozens of ants, not a mark or wound was discernible; yet if the slightest cut be made in the rim with a knife juices issue as from any ordinary caterpillar with an opening in the skin.

In concluding Mr. Dodd says that it is not all pleasure searching for *L. brassolis*, or for other insects, in the habitations of the green tree ant. This species is as plucky and determined as the fierce and dreaded "bull dog" and "jumper" ants and comes trouping in hundreds from all parts of the tree when a nest is disturbed. Then there is the multitude in the nest itself, also those in other nests, for often there are many nests in even a small tree. These ants are remarkably quick to get upon and spread themselves over an intruder. They do not waste their energies in biting one's clothing, but directly they reach the flesh they commence operations, and one's neck and arms suffer considerably. The bite of the insect is trifling, but it discharges a liquid onto the bitten spot which gives a sharp pain.

In approaching closely to an ants' nest, or to a place where they are in attendance upon scale insects, aphids, or other forms, they show fight unmistakably. While they are prancing and plainly showing that they are desirous of a closer acquaintanceship it will be noticed that the abdomens are held up and occasionally jerked forward. This jerking action means that the insect has brought his little "squirt" into play, a jet of decidedly acrid liquid being discharged therefrom, sent straight over its head, and capable of striking an object several inches directly in front before it assumes a downward tendency. Having received several of these jets, or part of them, in the eyes, on the lips, and often had the liquid in cuts and scratches, Mr. Dodd can testify as to its stinging properties. When hundreds of ants are sending forth these jets, which can be seen against the sun, it behooves one to be careful when in their immediate vicinity.

Mr. Dodd says that, though there are many interesting insects in Queensland, this green tree ant with its vast colonies, its curious

habit of using its larvæ as implements wherewith to spin its nests, and its queer and varied acquaintances, is the most remarkable of all.

Commenting on Mr. Dodd's account of the habits of *Liphyra brassolis*, Mr. E. Ernest Green noted that the fact that the larvæ are really carnivorous seems to be proved by their having seized and attempted to eat some of the ant grubs; but they do not appear to have been satisfied with that diet. He therefore asked, is it not possible that their proper food may be some coccid inclosed in the ants' nests? Mr. Green remarked that in Ceylon the arboreal nests of the same ant almost invariably include colonies of Coccidæ, Aphidæ, or Aleurodidæ.

Dr. T. A. Chapman described in detail three larvæ of *Liphyra brassolis* sent to England by Mr. Dodd. Two of these were apparently full grown, while the other was very much smaller. In these two sizes the larvæ are so very different that had they come from different places and possessed different histories one would never suspect that they were at all related.

The smallest caterpillar was 6 mm. long and 2.3 mm. broad and very flat, reminding one very much of the larva of *Camponiscus luridiventris* (a common alder saw-fly) in its general size and form; or, for that matter, of an ordinary *Lycæna* larva, if we make it first, colorless, then nearly flat instead of raised along the dorsal line, and, thirdly, if we somewhat exaggerate the rounded lateral projections of the segmental margins.

The segmental divisions as seen dorsally are 12, of which the first and last are terminal. White and soft as this larva looks, the margins, nevertheless, have something of the appearance and structure of the full-grown larva, having a strong chitinous binding divided into small cells.

The prothorax has a slight angle on either side, allowing the front between the two angles to be a transverse straight line. The head is beneath this, placed quite centrally, quite free from it, and capable of much movement, including probable protrusion in front.

The last segment visible dorsally is the ninth abdominal, and beneath this is the tenth carrying the anal prolegs. In a ventral view of the larva the true segmental divisions are very plain.

The prothoracic spiracle lies in the fold between the pro- and mesothorax, but the abdominal spiracles are each on about the middle of its own segment, placed dorsally, about half way from the middle line to the margin. Doctor Chapman did not detect anywhere any hairs or tubercles.

The nervous ganglia are very visible as reddish brown masses. There is a large one in the prothorax that represents the cephalic and œsophageal. The prothoracic proper is placed toward the pos-

terior margin of the segment. There is one each in the mesothorax and eight following segments. The last and largest of these, though in the sixth abdominal segment, appears to belong to the seventh and following segments, which are without ganglia.

The prolegs are of much interest when compared with those of the full-grown larva. They have a rather thick cylindrical base, and have the usual form of one row of crotchets, facing inward, 13 to 17 in number. On the anal claspers these are much smaller and few in number (9), and are similarly in one row. The true legs are short and thick, and terminate in very curved claws.

The head is small, about 2.5 mm. in diameter; it has in front (on the epicranium, clypeus, and labrum) a number of short stiff hairs, the largest about 0.08 mm. in length. None were seen elsewhere.

The antennæ are rather longer than this, but happen to be telescoped. The second segment is not in evidence. As found the antennæ are about 0.06 mm. long and 0.04 mm. thick, with a terminal armament of bristles, amongst which the third segment is not clearly discriminated.

The head itself is rather dark in color from being well chitinized; beneath it are three circles, carrying jointed palpus-like appendages of which the central one is largest and represents probably the labrum, with the other two as labial palpi. The two lateral ones, according to Doctor Chapman, are, however, probably the maxillary palpi, especially as they appear to have another ill-developed process.

The jaws are long, and cross one another for some distance. Each seems to consist of a straight conical process with only one sharp terminal point—a simple spike or dagger.

Doctor Chapman remarked that the large larva is a very different object. Looking down on its back there is to be seen an approximately flat surface, oval in form, rather narrower in front than behind, with a margin smooth, regular, uniform, and of the same texture, etc., all around, with no trace of segmentation. It measured 23 mm. in length by 15 mm. in width. When placed on its flat dorsal surface it stands up above the flat supporting surface about 5.6 mm., and shows a level, but not smooth, top, and smooth and sloping sides. The amount of slope may be seen by a comparison of the top and bottom; the top (the ventral surface of the larva) is 18 by 7 mm., as against the 23 by 15 mm. just mentioned. The slope is almost nil at the head end, and therefore so much the more elsewhere.

The dorsal surface and the sides are brown, hard, and chitinous. The sloping sides show little indication of segmentation, but at the margin of the open (and soft) ventral area they present a series of dark markings very slightly raised on rounded elevations, but

so shaded as to appear very much so. The small flat ventral area of the larva is pale and white, and is the only portion where any movement can possibly occur, the rest being a solid chitinous cap. Constructed as it is to permit this soft area to be absolutely covered and hidden on the surface on which the larva rests, one is surprised at its widening out above this area, quite regularly until, at a sudden sharp margin, the sides meet the flat top. The brown marginal marks are apparently two to a segment, certainly so at the sides where they are largest, and where a faint depression along the sloping sides seems to mark each segmental division. To see this, however, requires close examination, and some might say a little imagination.

Turning the larva over again to examine the back more carefully, we find the margin very sharp and slightly browner than the terra-cotta center. Laterally and posteriorly it is a little hollowed within the margin. Across the middle are three very distinct lines, darker in color, and with the surface in front decidedly higher than behind. They occupy the middle two-thirds of the surface, but do not invade the fourths on each side next the margin. In front and behind these the indications of the segmental divisions are very obscure. A faint indication of a dorsal ridge exists in front of these lines. There are also a number of dots that appear to be obsolete hair points, arranged in some degree as a transverse line across each segment, but with outlines enough to make such a statement a little doubtful or even misleading. The two segments marked out by the dorsal lines are the fourth and fifth abdominal.

The character of the sharp margin of the dorsal area needs a little more definite description. In the first place the out-sloping sides for their top millimeter cease to slope, but become vertical; then inside the sharp border the surface descends again steeply so as to form a sharp raised border to the central area. In front the inner slope soon bends into the flat dorsal area; behind it does so more slowly, resulting in the hollow before noticed. Around this portion there is, inside as well as outside the sharp margin, a breadth of about 1 mm., differentiated by a slight line from the general dorsal surface.

Seen microscopically, the whole surface consists of very minute raised dots, each carrying a fine point; on the marginal flange surrounding the dorsum these are modified into an arrangement that has just the appearance of overlapping fish scales.

The spiracles are difficult to find; in fact, Doctor Chapman failed to find the thoracic spiracle. The abdominal spiracles are precisely where they are in the small larva. They are very small, and differ little in appearance from the hair-dots noted above.

They are minute holes with no marginal structure. Some trace of the true spiracles can be seen at a little depth within them, accompanied by a scalelike outer margin.

Perhaps the most remarkable thing about this larva is the modification which has affected the prolegs. When we examine the soft under side of the larva the head, true legs, and prolegs are seen very much as in the young larva. The head, however, is nearly white, and so are the true legs except for the tarsal tips.

Beginning at the margin of the dorsal shield one finds that the shagreened points of the general surface carry hairs of various lengths, some almost evanescent, others nearly 0.25 mm. long. These no doubt assist in making the apposition of the larva to its resting place more complete. They seem to be true hairs jointed at the base, and the points on the dorsum are probably also really hairs rather than spicules.

The shagreened dots are about 0.08 mm. in diameter. As one passes inward from the margin the hairs get rather thicker, and retain their length of from 0.20 to 0.28 mm., the shagreened bases lose all chitinous color, and a short way in there is apparently a smooth surface thickly studded with white, short, thick hairs. As we approach the prolegs these get shorter and sharper, and fail altogether at a line just below the summit of the column at the top of which is the retractile portion of the leg. There, just at the margin of the summit of the column, is a compact circle of crotchets that differ in no very decided manner from those ordinarily found on prolegs. Within this circle is a white projecting mass of tissue with a ridge along its summit from front to back, with parallel striæ running down to the margin. The crotchets are hooked outwards, have a short flat base applied to the surface of attachment, and, without forming two or three regular rows, are in more than one row. The little smooth space outside them gives them room for movement without being interfered with by the hairs that clothe the rest of this under surface.

These circles of crotchets, which are to all appearance identical with the complete circles found on the prolegs of "micro" larvæ, are not the ordinary crotchets at all, but an entirely new structure. The true crotchets exist in the young larvæ, but in this full-grown one are merely represented by the striæ on the central fleshy mass noticed, which is really the true proleg. The crotchets here existing are around the summit of the pillar, at the center of which the true proleg is often placed. Doctor Chapman says that its method of working must be very similar to that of the "micro" full circle, but instead of having a central tendon as they have it has the

whole proleg structure by the movement of which it must be expanded and contracted so as to take and relax its hold.

The true legs are rather small and rather thick, and densely, or at least very closely and regularly, clothed with fine white hairs. They terminate in a claw, slightly hooked, slender as compared with the last joint of the leg, dark in color, making it look very strong and sharp, and capable of being flexed so as to fold up on to the last (tarsal) joint of the proleg, reminding one of the tibiæ of *Nepa* or *Mantis*.

The head is nearly colorless, about 1.7 mm. wide. Centrally below the mouth and pointing backward is the labium, or part of it, a pale conical rather than cylindrical process ending in a short chitinous tube (spinneret?). On each side is a long palpus (maxillary?) of three joints, the last very small, projecting ventrally and apparently with a fleshy process (maxilla?) toward the middle line. In front is a tolerably normal labrum, square and notched below, with a good many short hairs on its anterior surface. The antennæ are very long, about 1.1 mm., and regularly clothed with fine hairs; Doctor Chapman could not recognize a basal joint, if there be one; the next, therefore the first, is very long, 1 mm., and also thick, about 0.22 mm. The last joint is a small square piece about 0.1 mm.

The labrum is very fixed in its position and moves little. Doctor Chapman says that even if he is deceived in this matter by having only stiff preserved specimens to deal with he is certain that it fits down very closely and tightly laterally in the maxillary bases, leaving in front an oval opening between it and the labium within which the jaws are visible, with apparently some room for movement in the cavity thus formed.

Each jaw carries three teeth, each a long sharp spine capable of piercing, but certainly not of biting. Each jaw is probably capable of meeting the other, so that the teeth may interlock; but in the specimens examined one jaw is entirely in front of the other.

There are six eye spots, five of them in a circle, the other separate.

The head, which looks sunken into the white fleshy tissue of the under side of the larva, is really very moveable and has a definite neck (?), so that the mouth parts, which are at the front of the head and point more or less forwards, can be directed directly backwards between the true legs, exposing the front or dorsum of the head, which is rather longer than broad, nearly colorless, and has some hairs and the usual suture marking off the clypeus.

Doctor Chapman also had a larva of intermediate size which differed from the larger one in nothing except, perhaps, that the spiracles were more readily seen than in the full grown one.

The pupa which he had was very large, 28 mm. long, 14 mm. broad, and 10 mm. deep, while it was depressed in front in a way apparently due to pressure. Were the rounded contour of the dorsum and sides continued, its depth would be 12 mm.

It is typically lycænid in form, being very round at either end, broadest at the fourth and fifth abdominal segments, narrower thoracically; the head is beneath; there are no movable segments; there are no traces of cremastral hooks, or of any silken girdle; the first leg lies equally against head and antennæ. The maxillæ are well developed. They appear to contain no maxilla (the individual being close to emergence), but the labial palpi are very evident beneath them.

The most characteristic feature of the pupa is a set of flanges or raised ribs. If the pupa were divided into a dorsal and ventral piece by a section through its widest dimensions, the line of section would mark one of these ribs, which starts around the abdominal segments from the anal angle of the wings (end of vein 1*c*) and goes round the end of the pupa, dividing the last segment into two portions. This segment is consequently of considerable anteroposterior dimensions, stretching a good way under the pupa, but also having a portion, as it were, lifted right out onto the dorsum by having to be above the flange.

The segmental incisions are all raised into double ridges; but below the marginal flange above noted, though with no trace of anything of the sort above it, each segment has another single ridge or flange about one-third of the way in front of each incision. The scars of prolegs are well marked by large areas into which these ribs do not intrude.

Doctor Chapman remarks that these flanges are obviously the remains of the great marginal border of the caterpillar, and of the division beneath it of each segment into two. The marginal ridge extends forward through the wings; but the pupal shell is so delicate that it is difficult to say whether this ridge is in the wing covers or an indication of a flange on the segments beneath them showing through.

The spiracles are more obvious than in the larva, and occupy a similarly dorsal position. The pupa is very smooth and polished, at least thoracically; the abdomen has very numerous, almost microscopic, hair points.

Doctor Chapman also had a specimen of the pupa within the larval skin, which fully illustrated Mr. Dodd's account of how pupation occurs. The larval skin becomes a little altered by the dorsum being rather raised and rounded, but substantially it is the full grown larva one sees, and this forms a case or cocoon, precisely

as happens in the pupation of the Muscidæ. The pupa inside lies quite free from any attachment to the skin, but the ventral depression of the pupa is due to its having to fit on the ventral aspect of the larval skin, which is raised centrally by the head, legs, prolegs, etc.

The larval skin dehisces by cracking around the marginal crest in front and by a crack across the front of the three ridges—that is, between the third and fourth abdominal segments. The semicircular portion thus marked off again divides longitudinally into two portions. In Doctor Chapman's specimen one of these portions was missing, the other loose.

Dr. William M. Mann found several of the caterpillars of *Liphyra brassolis* at Tulagi, British Solomon Islands, in the leaf and silk nests of *Œcophylla smaragdina* var. *subnitida*. He remarks that these larvæ much resemble those of *Microdon* and glide along in a similar manner, though very much faster.

Euliphyra mirifica

All of our knowledge regarding the early stages of this curious form we owe to Mr. W. A. Lamborn whose observations were made at Oni Camp, 70 miles east of Lagos, Southern Nigeria.

Mr. Lamborn made a window into a nest of the "tree-driver" ant (*Œcophylla smaragdina* race *longinoda*) by snipping out a square piece of leaf with a pair of scissors, and on looking in he saw a larva which he recognized at once, as it was similar to one which he had previously seen assailed by these ants, but which had successfully protected itself by drawing down its hard carapace-like shield in limpet fashion to the supporting surface. He tore the nest open and discovered more larvæ, and thereupon took ants and all home in a tin box. He broke other nests open and found larvæ in four more, bringing up the total of larvæ secured to 19. The larvæ were not all of the same age in each nest.

He remarked that the head of this larva is remarkable. When the larva is at rest and usually when it crawls the head is completely hidden by a fold of skin which extends all around so as to form with the leathery skin of the back and sides a kind of carapace. The head is sometimes thrust forward under the fore margin of this fold, and one then sees quite a long neck gradually tapering to a point terminated by fine jaws.

As it crawls the larva frequently swings this proboscis first to one side and then to the other as if in search of food. It took Mr. Lamborn 48 hours to find out the source of their food supply, for they did not touch the leaves, and he did not see them attack ants

or ant larvæ; neither did they go near the dead insects which the ants had stored as food.

He actually saw one of these larvæ thrust its little proboscis into the jaws of a large ant and keep it there while the ant made movements as if feeding it. Sometimes, too, when a large ant was feeding a smaller one the latter retired in favor of a caterpillar. The caterpillars were frequently near with extended proboscis when the ants were ministering to their own male and female larvæ.

He noticed that the feeding does not seem to take place very often, and presumed that the high nutritive value of the material provided makes it unnecessary.

When the larva feeds the fore part of the body is raised and the margins of the lateral folds of cuticle are bent around until they meet, thus protecting the soft ventral surface. The head comes out at the apex of the cone thus formed.

The larvæ appear to be extremely slow growing.

The head and neck of the larvæ appear to be protected against attack, but the ants lose no opportunity of seizing other parts. He once saw a larva crawling with an ant fastened to one of its claspers, the abdomen only of the ant being visible, as the rest of its body was under the lateral fold of skin. He also saw a larva which protected itself by just settling down closely on the supporting surface, and when the ants retired it raised itself a little and crawled, but when they reappeared it settled down again.

Mr. Lamborn notes that observations on these larvæ are difficult, as interference with their nests causes the ants to remove to a new home nearly every time.

Some half-stupefied larvæ were put into an ants' nest. Such as happened to fall on their backs were immediately seized by the ants. Mr. Lamborn also found that a healthy larva placed on its back had difficulty in turning over and is in this position liable to attack. In one instance he saw a larva with an ant gripping it by the neck on the ventral side.

Two larvæ of this species each about 20 mm. in length collected by Mr. Lamborn were described in detail by Dr. Harry Eltringham. He noted that the dorsal and lateral views present an appearance recalling that of a mollusk rather than that of a lepidopterous larva. The ground color is brownish ochreous, and there are several irregular markings of a rich umber brown. The lateral portion of the larval skin is extended and modified into a kind of mantle, the edge of which touches whatever the larva may be resting on. From the edge of the mantle the sides, which present an irregular and wavy surface, slope up to the dorsal area, along the whole length of which is a deep groove bounded on each side by a hard

chitinous ridge, the latter, except at the extremities, being thrown into a series of deep curving folds. This dorsal groove curves down to the mantle edge rather abruptly at the hinder end, but more gradually at the anterior extremity. Round the edge of the mantle there are 24 dark brown spots, many of which are extended toward the dorsal region as irregular marks, and between these markings there are sometimes smaller spots of the same color.

On each side there are nine spiracles. The first lies just above the second dark spot of the mantle edge, the second is above the fourth spot, and the remainder correspond in position to the mantle spots beneath them. The third is placed very far up the side, the fourth is a little lower, and the remainder are still lower and in a nearly straight line.

The whole structure of the exposed portion of this remarkable larva is profoundly modified, presumably as a protection against the attacks of the ants by which in life it is surrounded.

The entire skin is covered with thick chitinous plates, which are irregularly radiate and have sloping edges. The projections of these plates interlock with the lateral cavities of those adjacent, and the appearance under a high power is not unlike that of a complicated armor sheet of cogwheels. Such an arrangement doubtless provides a very efficient protective covering with a maximum of flexibility. The plates vary considerably in size and in the extent to which the edges are sloped.

Microscopic examination shows that the brown markings on the larva are caused by the presence of small brush-like chitinous tufts, one of which arises from the socket in the center of each chitinous plate. In the unpigmented parts of the skin, from which these tufts are absent, the plates still have the sockets, so that at one period of its evolution the larva probably had the tufts, or at least some scale-like growth, on every plate.

Here and there in the armor, especially (probably exclusively) on the pigmented areas, there are small round openings, the edges of the adjacent chitinous plates being neatly hollowed, so that each forms its representative part of the circle. Doctor Eltringham suggests that possibly these apertures are the external openings of glands, though he had no proof of this. If, as he believes, they are confined to the pigmented areas, this would probably account for the correlated presence of the brush-like tufts, which may either protect the openings, or, as Professor Poulton has suggested, hold some attractive secretion prized by the ants.

The extreme outer edge of the mantle is armed with a regular fringe of flat, chitinous projections, their bases furnished with interlocking processes. On the upper side of each projection there is a

thin scale, very narrow at its socket, but increasing outwardly to about the same width as the projection on which it lies. The purpose of these scales is not very obvious, but possibly they may have a tactile function. Within the peripheral fringe so formed there is a row of thick elongated chitinous plates, the edges of which are provided with somewhat irregular interlocking processes. Each plate has a scale socket, but apparently does not bear either a scale or a brush-like tuft.

The spiracles have three slitlike openings, a long central one, with others less than half as long above and below. Doctor Eltringham says that most, if not all, of these have these openings, although it is sometimes difficult to be sure of the presence of all three. Protection is afforded by stiff pointed hairs, for the most part curving inward toward or over the spiracular orifices. Finally the hard chitinous ridges of the dorsal groove are armed with very short hooklike spines and there are a few spines or hairs on the underside of the mantle edge so arranged as to preclude entry if the mantle were raised at any part.

On turning the larva over its lepidopterous character becomes more evident. The head, three pairs of true legs, and five pairs of prolegs can now be seen. The true legs seem to become progressively slightly larger from in front backwards, while the last pair of prolegs are much smaller than the others. The prolegs are of what Doctor Chapman has described as the "macro" type, having hooks only on the inner margins of the feet.

The head calls for special remark, owing to its modification in adaptation to the habits of the species. It is elongated and somewhat conical in form, and when withdrawn there is around the base a deeply invaginated fold of cuticle. There are six ocelli, four of which are anterior and lie in a small semicircle, the remaining two being rather more posteriorly placed. The antennæ are placed laterally just above the labrum; and beneath the latter, and in a dorsal view concealed by it, are the mandibles. These have four ridgelike teeth. The maxillæ have two large lobes each with two small points, and in the actual specimen lie close together forming what looks like a pointed organ projecting from beneath the labrum, when viewed from above. There are large maxillary palpi, and the labrum is long and somewhat pointed and has on it a small papilla, possibly a tactile organ. There is some evidence of a second and smaller papilla. The mouth parts are exceedingly small and difficult to make out distinctly.

The pupa is attached in a peculiar way to a leaf, its suckerlike extremity being spread out and apparently cemented down. The larval skin is not completely shed, but is split open on the exposure of the pupa, afterwards remaining in this expanded condition.

In comparing these larvæ with the larvæ of *Liphyra brassolis* Doctor Eltringham notes that in the latter the cuticle is not provided with interlocking plates as in *Euliphyra mirifica*, but is covered all over with chitinous tubercles, and at the edges of the mantle is provided with numerous short setæ. There is no dorsal groove, and the cuticle is not thrown into ridges. As Doctor Chapman has stated, the spiracles are minute holes without marginal structure. The mouth parts are larger than in *Euliphyra*. The antennæ are certainly longer and more conspicuous, and the jaws are more adapted for piercing and tearing. The peculiar modification of the prolegs is not evident in *Euliphyra*.

Aslauga vininga

As was discovered by Mr. W. A. Lamborn at Oni Camp, in Southern Nigeria, the larvæ of this species are carnivorous, feeding upon tiny smooth hemispherical coccids (*Pseudococcus longispinus*, a common and widely distributed pest, and *Lecanium punctuliferum*) which are attached in colonies to the stems or leaves of different plants. On some leaves they occur in great numbers at the base on the under side, filling up the depressions between the main ribs and clustering also on the stem just below the insertion of the petioles (*Pseudococcus longispinus*), or on the stems of various plants, especially kola (*Lecanium punctuliferum* var. *lamborni*).

The coccids are attended by ants, which cover them with carton-like shelters composed largely of finely comminuted vegetable detritus among which there are fragments of bud scales and numerous unicellular epidermal plant hairs.

Aslauga lamborni

Mr. Lamborn found that the larvæ of this species present the same general characteristics as those of *A. vininga*, being oblong in dorsal view with lateral surfaces sloping downwards and outwards. They have a hard, tough, toad-colored skin covered with coarse rough tubercles evidently protective in function, which is extended down as a fold on all sides in carapace fashion so as to protect the softer lateral and ventral surfaces. The lower margin of this fold bears a fringe of very fine hairs, such as would efficiently prevent small insects from crawling underneath. The segmentation characteristic of lepidopterous larvæ is shown only by the presence of spiracles; but rather more than half way to the anal extremity is a deep transverse groove, the only region at which, owing to the leathery consistence of the cuticle, it is possible for flexion to take place. The cuticle is indeed so hard that a larva placed on its back is unable to bend itself sufficiently to turn over unaided. Toward the

hinder end of the body and just inside the spiracular line are two horny rounded eminences, one on each side of the mid-dorsal line. From these eminences pointed tubercles are from time to time thrust out, but no dorsal gland was detected. The tubercles appear to represent those of other Lycænidæ, in which, however, they are more externally placed, being just to the outer side of and behind the spiracles of the twelfth segment.

The head is small in proportion to the size of the larva, and there is a definite neck of sufficient length to enable the head to be thrust forward, or retracted in tortoise-like fashion under the shelter of the carapace. The anus is protected in a similar manner.

The food of the larvæ are little beady coccids *(Stictococcus sjöstedti)* found in considerable numbers immobile and firmly fixed to the young shoots of certain plants. These coccids yield a watery secretion much in demand by ants; it is not sweet to the taste, but has an aromatic flavor rather suggestive of turpentine.

The coccids are usually surrounded by a multitude of ants. The ferocious "tree-drivers" (*Œcophylla*) do not eat them, but seem, like the other ants, to visit them for some food material. Mr. Lamborn noted that the ants not only attended the coccids, but ran all over the lycænid larvæ. The ants often roof over a number of the coccids with a thin covering composed of particles of bark and other vegetable débris so as to form a convex chamber which fits down on all sides around the inclosed insects. The chambers are about the size and shape of a half hazelnut, and are tenanted by ants as well as coccids.

Mr. Lamborn is disposed to think that in some cases lycænids find food where these bodies have been, for some stems frequented by the butterflies look as if they had borne the coccids.

The first caterpillar found, brown in color and resting motionless on the stem, looked so very like one of the ant-constructed chambers that it had a narrow escape from injury, for Mr. Lamborn actually attacked it with scissors under a mistaken impression as to what it really was, his custom being invariably to explore these chambers.

Mr. Lamborn records that within a period of 24 hours one larva consumed 12 out of 15 coccids at its disposal, and another 16 out of 28, a few basal portions still remaining attached to the stems supplied both larvæ. He found that the larvæ would eat these coccids whatever the plant they happened to be attached to.

Lycæna arion

In a note published in 1899 Mr. A. B. Farn wrote that he had had experience with the larvæ of *Lycæna arion* for some three years, rearing them up to a certain point from the eggs laid by females

taken by himself. Although he had failed to get them to pupate, he had had the larvæ nearly, if not quite, full grown.

The color of the larvæ he had was more or less lilac, this color becoming more brilliant as the larvæ increased in size until it might almost be described as violet. At this period they spun together the seed heads of the thyme, but he never succeeded in finding them alive in the spring following.

Mr. Farn wrote to Mr. F. W. Frohawk that the eggs laid by the females under perfectly natural conditions are laid singly (he found only one exception) and are inserted somewhat deeply among the clusters of buds of thyme. He could not discover any eggs on thyme in full bloom, and remarked it would seem that the buds are chosen so that the hatching of the larvæ and the opening of the buds should be contemporaneous.

In 1903 Mr. Frohawk wrote that from observations he had made the preceding year he felt convinced that some connection existed between the larvæ of *Lycæna arion* and the common yellow ant (*Formica flava*) by the preference shown by the butterfly in selecting the thyme growing on ant hills for oviposition.

From July 5 to 17, inclusive, he found *L. arion* numerous. During this period he watched several females laying eggs and on the last day saw four females laying their eggs on thyme blossoms on the top of an ant nest.

The thyme grew in patches among the short turf, which was composed of the usual small plants which clothe the surface of the Cornish downs, and with a few furze bushes dotted about, and on the ant hills. But the plants selected were those growing in the open and some distance from the furze bushes, and therefore fully exposed to wind and rain.

Under every patch of thyme visited by the female butterflies he found ants' nests. He also saw other females lay eggs on the thyme growing on ant hills, and also on the thyme upon the turf walls where ants are likewise in abundance.

On July 29 he found two larvæ, which he had raised from eggs deposited on potted plants by several captured females, rolling about together under the thyme blossom. On close examination he found that the smaller one had seized the larger with its jaws, which were buried in its side, and was apparently sucking it. Upon pulling them apart he placed the victim under the microscope and found a deep hole in its side, with the surrounding surface shrunken and liquid exuding from the wound. He remarks that this conclusively proves the cannibalistic habits of these larvæ, which he had always suspected, as on previous occa-

sions large numbers of larvæ had disappeared in a mysterious manner.

He then placed about 50 larvæ on as many sprigs of thyme so as to keep them separate and under very close observation. On August 11, many of the larvæ having passed their third molt, when they cease feeding on thyme, he started to investigate what relation there might be between the larvæ and ants, thinking that in all probability they might feed either on the larvæ or pupæ of the latter.

He had previously found that after the third molt the larvæ persistently refuse to remain on thyme blossoms, or indeed on any other part of the plant, and appear to have a tendency to hide in the ground. Although thyme and various other plants were supplied to them, they refused to feed, so, leaving them with a growing plant of thyme and keeping them under conditions as natural as possible, trusting they would hibernate in that stage, he left them undisturbed; but subsequently nothing more was seen of them.

He at first selected one of the larvæ after the second molt to experiment with, as he found that after the third molt they do not attack each other. Their cannibalistic habits only exist during the first three stages.

He supplied this larva with an ant's cocoon with one end removed. It at once began eating it. He then placed the two objects under the low power of the microscope to watch carefully the proceedings, which were interesting. He watched it feeding on the jellylike substance of the pupa, as well as the cocoon, which it ate in the same manner as it would a leaf, by biting the edge.

So far this seemed satisfactory, as he thought he had found the right food for the larvæ in their subsequent stages; but this proved not to be the case.

Having found a dead *L. arion* larva, he placed it in a box with some ants, which immediately seized hold of it, apparently intending to kill it.

He then put a living larva in another box with four ants (*Formica flava*), and expected them to treat it in the same way, but was surprised to find them act quite the reverse. They all immediately ran to it and, waving their antennæ over and upon it, at the same time closed their jaws, and then apparently smelt and licked it, and seemed particularly attracted to the hinder part of its back, about the tenth segment. First one and then another of the ants would run over the larva, and then stop to lick that part of its back. He then noticed that a tiny bead of moisture appeared, and one of the ants touched it with its mouth, which instantly caused the bead to disappear. He afterwards placed both larva and ants under the

microscope, which at once revealed the cause of attraction, for there on the tenth segment he found a small transversely elongated gland on the dorsal surface.

He then examined with the microscope another larva in the same stage while it was feeding, during which operation the gland is kept throbbing. So he placed the ants close to it, and soon saw them run over it. Directly a foot touched the gland, or the region adjacent to the gland, it throbbed more violently and swelled up. It then exuded a globule of clear white liquid. At the same instant an ant licked up the drop. In a few seconds an ant's foot again touched the gland, and another bead of liquid oozed out, which was at once again licked up by an ant.

An interesting fact was that the larva did not heed the ants running over and around it while it kept feeding; but the gland is apparently extremely sensitive to the touch of an ant's foot.

He several times touched the glands of several different larvæ with the point of a very fine sable-hair brush. This caused the larvæ at once to wince and to contract; but in no way could he induce the exudation of the liquid. But as soon as an ant's foot, or the claws of the foot, touched it a bead would appear, to be at once imbibed by the ants.

Although the larva was kept in a box with numerous ants, both workers and winged females, together with their pupæ, not one attempted to bite it; as soon as they touched it they slowly closed their jaws and waved their antennæ over and upon it.

The larvæ appeared to be perfectly at home with the ants, neither molesting the other. After the third molt Mr. Frohawk was unable to perceive any attempt at cannibalism among the caterpillars, although this habit exists in all the earlier stages.

On July 12, 1905, when in company with Mr. A. L. Rayward, Mr. Frohawk discovered a living pupa of *Lycæna arion*, and near by a pupa case of a freshy emerged female which Mr. Rayward detected at rest.

As described by Mr. Frohawk the pupa bears a general resemblance to the pupa of *Lycæna ægon*, except for its much larger size, measuring half an inch in length. In dorsal view across the middle its greatest width is three-fourteenths of an inch. The head is obtuse, the base of the wings is slightly angular and swollen, the wing is slightly concave, and the abdomen is swollen at the third and fourth segments, becoming thence attenuated and rounded posteriorly.

In side view the pupa measures three-sixteenths of an inch across the middle. The head is rounded, the thorax convex and rising into a slight dorsal ridge, the metathorax and first abdominal seg-

ment sunken, the abdomen swollen in the middle and curving to the posterior segments, which are rounded. The anal segment is appressed to the ventral surface. The cremastral hooks are absent. The wing is ample, swollen, and rounded across the middle; it extends to the fifth abdominal segment.

The entire surface is minutely granulated and covered with very fine reticulations of a deep amber color. The spiracles are prominent and blackish, the surface posteriorly adjoining them beset with a number of shining raised beadlike processes, some bearing minute amber-colored spines which have the apical half branched with extremely small bristles.

The color when first found was uniformly ochreous, with the eyes dark leaden gray. It gradually turned darker on the head, thorax, and abdomen. The wings remained ochreous, but showed leaden gray hind margins. Then the median wing spots appeared, and soon the whole pupa began to deepen more uniformly until it assumed a deep leaden gray all over, and remained unchanged for over 30 hours. A perfect male emerged at 8.30 a. m. on July 16.

It was on June 3, 1906, that Mr. Frohawk, in company with Mr. A. L. Rayward, first found the larva of *Lycæna arion* in its last stage. On arriving at the locality where they had previously watched the females laying eggs, they set steadily and systematically to work, closely examining every particle of growth and of the surface of the ground. This occupied the whole of the first day and half of the next; the intervening night was spent in making a careful search by lamp light.

As this all proved fruitless, they then determined on searching all the most likely looking ants' nests. First one, then another was carefully dug up and searched without any satisfactory results; but knowing that the object of their investigations must be somewhere in the immediate vicinity, they continued their task, when at length, on shaking part of the crown of a nest over a cloth, a goodly sized plump cream-colored grublike larva fell out, which Mr. Frohawk instantly identified as a full-grown *arion* larva.

In the same small portion of the ant's nest they found three more. Of the four, three were of almost similar size, about nine-sixteenths of an inch in length, and one was a good deal smaller, only three-eighths of an inch long.

These four larvæ were only just beneath the surface among the roots of the little plants of grass growing with the thyme. The soil surrounding them was loose and friable, having been worked up by the ants.

In company with the caterpillars there were ants and their larvæ and pupæ.

Although Mr. Frohawk had not yet been able to ascertain the actual food or manner of feeding, he thought that there could be but little doubt that the larvæ are tended by the ants (*Lasius flavus*) in the same way that their own larvæ are fed from mouth to mouth with the food the ants disgorge.

In 1915 Dr. T. A. Chapman published further observations on the last stage of the larva of this butterfly. He noted that the majority of European "blues" hibernate as larvæ in their third stage, having in all five stages. Others hibernate as full grown and full fed larvæ, others as pupæ, and some as eggs. Each of these habits is adopted by more than one species.

Lycæna arion differs from all of these and agrees with no other species in its method of passing the winter. Living on thyme, chiefly the flowers, it reaches the fourth and last stage some time in or about August, and then goes into hibernation. When it does this it is so small that it is difficult to believe that it does not have at least one more molt in the spring, though this is not the case. The little caterpillar only one-eighth of an inch long grows to its mature dimensions of well over half an inch and correspondingly thick without a change of skin.

On May 14, 1915, on pulling up plants over a nest of *Myrmica scabrinodis* var. *sabuleti* and disturbing the soil at a point close to overhanging heather, etc., a larva of *L. arion* was found. It seemed to be amongst loose earth that the ants had worked over, and if not actually in the ants' nest was within less than an inch of ground actually occupied by the ants. The larva was found near the surface, but precisely where in relation to the ants was not ascertained, the earth being broken up before the larva was seen. But it was certainly not in any permanent tunnel or chamber of the ants' nest, but more probably amongst the looser surface material brought up by the ants and not yet consolidated and amongst which, in weakly constructed chambers, the ants disposed of their larvæ temporarily on fine warm days.

The length of the larva was 11 mm., and its thickness about 3 mm. Its color was a pale earthy flesh color with no trace of green anywhere, and the impression it gave was that it must be a concealed feeder.

Unfortunately in the rough process necessary in disturbing plants and soil the larva suffered an injury, so that the hope of discovering what it would eat was unavailing.

There were visible some dark contents of the posterior extremity of the alimentary canal shining through the ventral surface; elsewhere the larva was too opaque to show whether there was anything of food material in its interior. The dark mass seen through

the lower surface was the posterior portion of the gut full of a dark material. It measured 3 mm. in length and over 0.5 mm. in thickness, and was rather hard and solid. Farther forward in the gut there were also portions of contents, rather soft and easily pressed flat on a slide.

The posterior portion of the dark mass was rather shorter and more slender than the forward portion. It showed a quantity of granular material in layers of darker and lighter appearance. The forward portion seemed to consist of a mass of minute hairs of fairly uniform size and structure. The less dense material found farther forward in the gut showed a number of identical hairs, and also some small triangular chitinous bodies very like mandibles of some insect.

On comparison Doctor Chapman found that the hairs in the *arion* caterpillar agreed absolutely with the hairs of the fully grown larvæ of the ant *Myrmica scabrinodis*, while the chitinous triangles agreed exactly with the mandibles of the same larvæ. Nothing of a vegetable nature was found amongst these contents, and it could not be doubted that the caterpillar had eaten many ant larvæ, and nothing else for a long time.

Doctor Chapman remarked that it seems highly probable that the caterpillar of *Lycæna arion* in its last stage behaves as do the larvæ of many bees and wasps, various parasites, and other insects that live on material that is practically all digestible and contains very little effete matter: that is, it does not, until it has completed its growth, evacuate any of the contents of the gut, but allows all the undigested material and effete matter to accumulate in the rectum during the whole period of growth, to be ejected when the period for pupation approaches. Such a procedure is not known in the case of any other butterfly.

The posterior and therefore earlier portion of the waste matter gave no indication of what food it represents, though the later portion represents many ant larvæ all apparently in their last stage.

Doctor Chapman raises the question whether the first portion represents eggs or young larvæ of the ants that were more thoroughly digestible and so left no recognizable detritus, or whether the earlier diet was a vegetable one.

At a meeting of the Entomological Society of London, held on November 7, 1917, Capt. E. B. Purefoy exhibited a short series of *Lycæna arion* which he had bred from the egg. After the third molt they had been carried into the nests of *Myrmica lævinodis*.

At the same time Mr. Horace Donisthorpe corroborated an observation of Doctor Chapman's that the ants, on being disturbed, carry off the larvæ of lycænids, beetles, etc., before removing their own young.

On November 20, 1918, Captain Purefoy exhibited a score of home-bred *Lycæna arion*, together with their pupa cases. He pointed out that the fully fed larvæ seldom, if ever, attempted to crawl far away from the ants in order to pupate. Larvæ which he had kept both in the nests of *Myrmica scabrinodis* and of *M. lævinodis* generally fed in chambers deep down in the nest where the small ant larvæ in their last stage are cared for by the workers.

When the *arion* larva was fully fed it generally remained where it was among the brood, slowly changing color from a fine ochreous hue to a dead gray white. Six or seven days might elapse before the larval skin was cast. The ants were running over their guest all the time, but never attacked it, even when the fresh pupa was at its softest.

The cremastral hooks would finally lose their hold of the silk pad, and the pupa would lie at the bottom of the little earth chamber.

When after 24 days or so the imago emerged it had to find its way to the surface through the ant passages. This it never failed to do, and the freshly emerged butterfly would be found during the early morning drying its wings on the herbage growing on the nest.

The egg of this species, as described by Mr. Frohawk, is one forty-eighth of an inch in breadth and one-eightieth of an inch in height. It is of a very flattened globular form, sunken in the center, so much so that to the naked eye the operculum appears as a dark central spot. The entire surface is finely and beautifully reticulated with an irregular net work. The color is pale bluish white.

Some eggs received by Mr. Frohawk from Mr. A. B. Farn on July 9, 1896, hatched on the following day.

The larva directly after its emergence is exceedingly small, measuring only one thirty-second of an inch. It is rather stout in proportion. The segmental divisions are deeply defined, and with a longitudinal dorsal furrow. On the first segment there is a large dorsal darkly colored disk, and a smaller one on the anal segment. The color of the body is pale ochreous yellow, tinged with greenish. On the dorsal surface are longitudinal rows of glassy white serrated hairs, placed in two pairs on either side of each segment above the spiracles. The hairs of the dorsal row all curve backwards. The anterior hair on each segment is much the longest, and all have pedestal-like bases of an olive color. The hairs of the subdorsal pair are both short, the anterior curving forwards, the posterior backwards. Below the spiracle, which is black, are three brownish serrated hairs placed in a triangle, all of which project laterally and have dark bases; the central one is very long. Below these, on the first lateral lobe of each segment, is a single simple white hair, and two other similar ones are found on the base of each clasper.

The head is of a shining olive black. The whole surface of the body is densely sprinkled with blackish points, giving it a rough appearance, and adding to the appearance of the depth of the segmental divisions. The legs and claspers are similar in color to the body.

A larva in the second stage measuring one-twelfth of an inch in length is thus described by Mr. Frohawk.

The first and last segments are flattened, projecting, and rounded, overlapping the head, which is withdrawn while at rest, and the anal claspers. The body is much arched, having a considerably elevated medio-dorsal ridge. The sides are flattened and slope to a lateral ridge; the under side is also flattened.

The ground color is a pearly white, thickly studded with very minute blackish points, and scattered over the whole surface are a number of bristles, varying in length, all having bulbous dark shining brown bases. The longest are situated on the dorsal and lateral regions. The spiracles are shining dark brown. The segments are beautifully marked with purplish pink, forming longitudinal stripes, the most conspicuous being the medio-dorsal and lateral stripes. The three other stripes, two above and one below the spiracles, are made up of oblique markings. The head and prolegs are brown, and the claspers whitish.

Mr. Frohawk noticed that there is a remarkable similarity between the buds of thyme and the larvæ, both in their coloring and in their pubescence, so much so that it requires very close examination to discover the little larvæ. They generally conceal themselves inside the blossom, making detection all the more difficult, but usually a small hole is eaten through the calyx, when the larva may sometimes be seen with only the anal segment protruding.

A larva in the third stage one-eighth of an inch long was similar in coloring, pattern, and structure to the one just described, except that it was brighter, the hairs a good deal longer, and the head shining black.

This third stage larva molted for the third time on July 26. Twenty-four hours after molting it still measured only one-eighth of an inch when fully extended. The general coloring was now more uniformly ochreous pink, and duller. The second and third segments were humped. The first segment was sloping to the front, sunken in the middle, and rounded, overlapping the head, and bore a large black oval patch in the center. The three posterior segments were also compressed and sunken. Each segment was humped subdorsally, forming a deep longitudinal medio-dorsal furrow. The sides were concave, and the lateral ridge projected and overlapped for the entire length, hiding from view the legs and claspers. There

were four longitudinal rows of long curved hairs, one being subdorsal and one lateral. Each row was composed of a single hair on each segment from the fourth to the ninth, inclusive, the subdorsal series ending on the last. The first three segments had each a set of three subdorsal hairs, those on the first segment curving forward. The lateral series were likewise formed of one on each segment, all directed laterally and surrounding the extremities of the larva. The hairs have the bases of remarkable formation, resembling glass-like pedestals with fluted sides. The entire upper surface of the body is densely studded with extremely minute pyriform glassy processes. The under surface is just as densely clothed with very short stoutish hairs. The head is ochreous, with dark brown markings in front. The prolegs are dusky, and the claspers are unicolor on the under surface.

As described by Mr. Frohawk the honey gland of the larva after the third molt is of peculiar construction, being formed of flexible tissue and surrounded by numerous glassy white pyriform processes varying in size, some of which are extremely minute. Those bordering the edges of the gland are furnished with excessively small white bristles, each process bearing four or five arranged in the form of a fan with diverging points; all are directed toward the central aperture, the whole forming a fringe surrounding the gland, and are obviously for the purpose of holding the bead of liquid in place, and probably also serve as a protection for this apparently sensitive organ.

The fully grown larva is seven-twelfths of an inch in length. The third molt is the last, after which every part, as determined from a careful microscopical examination of all the structural details by Mr. Frohawk, remains absolutely unchanged. This accounts for its extremely small head, which is out of all proportion to the size of the larva, but which was of proportionate size directly after the third molt when the length was only one-eighth of an inch. The small black dorsal disk on the first segment now appears as a mere black speck. The head is set on a very flexible retractile neck which can be readily protruded beyond the first segment when the larva is in motion, but when resting the head is completely hidden and withdrawn into the ventral surface of the segment.

In a dorsal view both anterior and posterior segments are rounded, the body gradually increasing in width to the tenth segment. The segmental divisions are deeply cut, each segment being laterally convex.

In a side view the first anterior and the last posterior segments are somewhat flattened dorsally and projecting laterally. The second-ninth segments are humped dorsally. The medio-dorsal furrow

usual in lycænid larvæ is only indicated on the posterior half of each segment. The sides are sloping and convoluted to the spiracles. The lateral ridge is dilated, swollen, and prominent, but rounded, and the ventral surface is full and of a bulbous character. The rather small feet are well provided with strongly curved hooks.

All of the other structural details are as in the larva after the third molt; but on examining the fully grown specimen Mr. Frohawk found that all the long dorsal hairs had been broken or worn off short, leaving only a series of basal stumps.

The color is a pale creamy ochreous with a pinkish lilac tinge along the lateral ridge and surrounding both the first and last segments.

When first found the entire skin had a shining distended appearance as if too tight for its obese proportions.

Doctor Chapman found that in a nearly full-grown larva the honey gland, which is so conspicuous in the autumn larva, owing to its comparatively large size, remains of the same size and therefore looks extremely small owing to the expansion of the rest of the larva. He is inclined to regard it as still functional, the four circles seen at the bottom of the hollow being very distinct. He says that possibly, however, these would look just the same if the function were in abeyance, although they are certainly a feature of all functional honey glands that he has examined.

This remarkable caterpiller passes over 10 months of its existence in its last stage, succeeding the third molt.

The full-grown larva described by Mr. Frohawk pupated on the surface of the ground free of web. At first the pupa is a clear, pale apricot yellow, which very gradually deepens to a dark amber color, excepting the wings, which remain light ochreous.

Lycæna arionides

Dr. T. A. Chapman remarks that this species which, though distinct, is exceedingly close to *L. arion*, probably has the same larval habits.

Lycæna alcon

On October 2, 1918, Dr. T. A. Chapman exhibited before the Entomological Society of London a bred specimen of *Lycæna alcon*, probably the first specimen that had ever been bred, certainly the first from larvæ taken in the autumn.

The larva of this species, which is green, has a well-developed honey gland. The eggs are generally laid on the calyx, and many flower heads have a large number of eggs on them, probably each laid separately. The caterpillars live amicably together, being devoid of the fiercely cannibalistic habits characteristic of the larvæ of *L. arion*.

Doctor Chapman noted that the life history is interesting as being parallel to, though differing from, that of *L. arion*. The young larva feeds in the autumn in the flowers and other portions of *Gentiana pneumonanthe*, and probably of other gentians. So far it is exactly parallel in growth to other blues, such as many of the English plebeiids that pass the winter in the third instar. When it reaches the third instar it leaves the plant, wanders off, and hitherto efforts to carry it further have failed. At this point it agrees with *L. arion* in habits, but it is not like *L. arion*, which is in a remarkably modified and concentrated (as regards skin armature) fourth instar, but is in quite an ordinary third instar. In its plant life it has differed also in that several, often five or six, larvæ live amicably together in one flower, whereas *L. arion* is solitary, and if by accident two larvæ meet, as by a second egg having been laid on the same flower head, or especially when incautiously associated in captivity, they are inveterate cannibals.

The remaining history is that both *L. arion* and *L. alcon* live in the nests of ants—Doctor Chapman kept both species in those of *Myrmica scabrinodis*—and pupate in the nest. The differences are that *L. arion* eats the ant brood, whereas *L. alcon* certainly sucks their juices without eating them; and Doctor Chapman could not prove that it ever actually ate them, though he thought it did so when past the winter when its food would more often be ant pupæ.

L. arion is in its fourth instar and is provided with a skin armature not unsuitable to it when fully grown. *L. alcon* has only a third instar armature, and when full grown might be almost described as without one for, like *L. arion*, it does not molt after entering the ants' nest, but attains its full growth still in the third instar. The skin is then so attentuated that the fat masses are very obvious, and its general aspect is like that of an internal feeder rather than that of a butterfly. Doctor Chapman remarks that it is to be noted as exceedingly remarkable that a butterfly larva should attain its full growth after only two molts.

M. Oberthür, who is familiar with localities where *L. alcon* is common, considered it highly probable that it had a life history similar to that of *L. arion*, and with the assistance of Mr. Harold Powell, found that ants would carry off the larvæ of this butterfly, and also that the larvæ would lap up the juices of wounded ant larvæ. He provided Doctor Chapman with the young larvæ used for observation both in 1916 and in 1917, and his success in rearing the insect was, he says, entirely due to M. Oberthür's initiative.

Mr. Powell saw the larvæ of *L. alcon* carried off by *Tetramorum cæspitum* and by *Tapinoma erraticum*. Acting on this hint Mr. Donisthorpe provided himself with a nest of *Tetramorum*, and now

has a caterpillar of *L. alcon* thriving in it. At the same time Mr. Chapman had larvæ in the nests of *Myrmica scabrinodis* and *M. hævinodis*.

Doctor Chapman observed that when ants were placed in a new nest they refused to accept a larva of *L. alcon*, although they willingly accepted that of *L. arion*.

Spalgis epius

Mr. Lionel de Nicéville in 1890 published a note sent him by Mr. E. Ernest Green from Pundul-oya, Ceylon, in which he said: "I have several times reared an insect indistinguishable from *Spalgis epius* from a carnivorous larva that associates with and feeds upon *Dactylopius adonidum* (the 'mealybug' of planters). My larvœ were dull olive green above, with numerous minute dark bristles and a lateral fringe of brown hairs, beneath pale green, slightly suffused with pink on the anterior segments. It partially covers and conceals itself with the mealy secretions from the *Dactylopius*. Pupa various shades of brown, wing cases pale." Mr. de Nicéville added that the larva is furnished with long irregular divergent processes, as in the larva of *Rathinda*, but here the tubercles appear to be arranged more regularly, while some are much shorter than others.

Mr. E. H. Aitken in December, 1891, saw a female *S. epius* flying suspiciously about a bush and thought it might be laying its eggs. This led him to examine the plant, and almost at once he found an unmistakable lycænid pupa. Then he instituted a regular search, but not a larva could he find, nor any trace of one. The leaves of the plant were nowhere eaten, and it was too much infested with "mealy-bugs" to afford fresh wholesome food to delicate insects. He had almost given up the search when he noticed that some of the bugs were enormously large. He brushed the white woolly secretion off of these, and they were uncommonly like lycænid larvæ. They were of the wood-louse form so common among the larvæ of that family, of a dark greenish brown color, with a few hairs scattered over the back and a fringe of bristles running along the side and around the front where the second segment conceals the head. With this fringe he saw them shovel a quantity of the white stuff onto their backs and clothe their nakedness after he had denuded them.

Watching them with a lens, he saw that they were feeding among the "mealy-bugs." They would pass over the larger individuals and bury their heads in the downy covering of a little one, and though he could not say he actually saw that they devoured it, he was quite satisfied that this was what they did. So he secured a number and

put them in a pill box with a supply of their prey, and in a few days the prey had disappeared and the larvæ had become pupæ. In a fortnight, exactly twice the time required by the smaller Lycænidæ generally, five specimens of *Spalgis epius* emerged.

Mr. Aitken was very much surprised at his discovery, for he did not then know that any butterfly larvæ were carnivorous, except when they indulged in cannibalism and ate each other as Lycænidæ often do.

When he found his specimens he was traveling in haste through a very wild part of the country, so he put the pupæ away without examining them. Later he obtained two more. On examining them with a lens what was his astonishment to find a face totally different from that presented by the African species (*S. lemolea*) but even more lifelike and expressive. Ears were wanting, but every other feature was there. The abdominal portion of the pupa formed the forehead, two gleaming black spots, exactly in the right place, made a most malignant pair of eyes, the arched thorax was the nose, the effect of which was heightened by its being almost black at the muzzle, and the head, with its attachment to the thorax, formed the chin and lips.

Mr. Aitken says that no description can convey any idea of the way in which the contour, features, and expression are worked out, and he is afraid that the figure on his plate will be regarded as overdone. To this he can only reply that it is underdone.

In Ceylon Mr. E. Ernest Green on more than one occasion found the caterpillars of this species inside the nests of a tree ant (*Cremastogaster dohrni*) feeding on the "mealy-bugs" (*Dactylopius*, sp.) inclosed therein.

Spalgis epius is found in Burma and the Mergui Archipelago, throughout India, and also in Ceylon. In the Kottawa Forest at Galle, Ceylon, it is very common and easy to capture, frequenting shady places and high jungle. Elsewhere, while it really can not be called rare, it does not seem to be common.

Besides the following from Africa there are about half a dozen additional species of *Spalgis* occurring from Hainan southward through the Malayan Islands to the Moluccas. Presumably all of these are carnivorous in their younger stages.

Spalgis lemolea

On January 19, 1891, the Rev. A. C. Good wrote to Dr. W. J. Holland from Kangwe, on the Ogové River, West Africa: "To-day I stumbled upon the queerest object which I think I ever saw. On

the under side of the leaves of a frangipanni I saw a number of small chrysalids which bore a most absurd resemblance to a human face. I found a few of the larvæ still unchanged. Their color was dark brownish. * * * The body was all covered over with a whitish substance not a part of the body, and which I took to be the remains of plant lice with which the underside of the leaves on which the larvæ were found abounded. I think that these caterpillars must have fed upon these white plant lice, for I could not detect that they had eaten the leaves. * * * The chrysalis is attached to the leaf by the back of the head, and presents to view in a wonderful way the face of a man or a chimpanzee. Especially do the eyes and the well-marked brows overhanging them present a startling resemblance to the human face. The natives notice it, and are surprised at the resemblance as much as I am. Here is mimicry, but to what possible purpose? Or has Dame Nature for once laid aside her usually practical character and decided to amuse herself?"

Mr. W. A. Lamborn, writing at Oni Camp in southern Nigeria, said in a note dated September 17, 1911, that he had now found another kind of lycænid larva, perhaps *Spalgis lemolea*, consorting with aphids or tiny coccids, on the under side of leaves. He saw several of these butterflies near the tree in the clearing, but did not make out "why they come there in the face of a strong breeze which is now blowing almost constantly." On October 3 he wrote that all the larvæ were found among coccids on a shrub in Oni clearing. Each larva bore a covering of gray material, which looked to him as if it were composed of cast skins of coccids, and he thought that they must have eaten these or their products, for they did not eat leaves. He was told that the plant on which they were is a species of *Croton*, but he rather doubted it. The larvæ were all found on the under side of leaves and always among the coccids.

Mr. Lamborn found the larvæ of this species feeding on two species of coccids which were determined as *Dactylopius virgatus* var. *madagascariensis* and *D. longispinus*. He had repeatedly examined the coccids without detecting the larvæ, and it was only his attempt to find a particularly large coccid for examination that led him to turn one over and to discover it to be lepidopterous.

The larvæ of this species did not strike him as being much larger than the coccids on which they feed, for they are rather flattened and usually nestle up closely to the masses of coccids under what appears to be a common covering of shed cuticles, etc. It is sometimes really quite difficult to distinguish them. The coccids are so closely packed and so well covered that one can rarely see the form of a single individual. It is quite common to see tiny coccids wandering in the material on the back of the larvæ.

FENISECA TARQUINIUS

Occurrence and habits.—This curious little butterfly has a very wide range, occurring from Nova Scotia, Quebec, and Ontario southward to northern Florida and the Gulf coast of Louisiana and westward to Texas and the Rocky Mountains. Prof. C. V. Riley said that it is also found in Asia, but this is an error.

It is very local and consequently is seldom taken in general collecting, but once its favorite haunts have been discovered it is easily secured in quantity.

Although collecting butterflies in Newtonville, Mass., and in the surrounding region, and about my summer home in Manchester, Mass., from 1890 until 1900 I never found it. In 1910, however, I caught one in my front yard, the first I ever saw alive. In 1923 I made a special search for it and located nine thriving colonies in Newton (1), Newton Center (1), Newtonville (4), Auburndale (1), and Weston (2). All of these colonies were singularly similar. They were all centered on the woolly plant louse of the alder (*Schizoneura tessellata*), and in all cases the alders were growing close to running water in small meadows with wooded hills about them.

In 1924 I found a colony in Essex, Mass., on the main road from Manchester just beyond the Manchester town line. This was a year in which *Vanessa cardui* was exceedingly abundant, and consequently was a poor year for other butterflies. It was exceptionally dry, and the aphids did not thrive. The few aphid colonies found in Essex and in Manchester did not seem to grow, and except for one were quite neglected by the butterflies. Three of the four colonies in Newtonville were revisited. Aphids were very few, and there were no traces whatever of the butterflies or of their larvæ, though in the year preceding about 100 examples of all stages had been taken from them without apparently at all diminishing their numbers.

In 1925 the colony in Essex found in 1924 numbered about as many caterpillars as in the year preceding, and caterpillars were found in other aphid colonies about a mile away which the year before had yielded none. Caterpillars were also found near Gravel Pond in Manchester. Of the three colonies in Newtonville one was without caterpillars or butterflies, two butterflies were seen about another, which showed evidences of the ravages of caterpillars though none were found, and the third yielded a single caterpillar and showed no traces of any others. All three of these localities have now succumbed to building operations.

This shows how uncertain is the occurrence of this insect in any one locality.

Single butterflies far away from alders were seen in Newtonville, in a field and in the front yard of my house; in Essex in a bog; and in Manchester on the tennis courts of the Essex County Club.

Mr. S. H. Scudder wrote that this butterfly is found only in the neighborhood of water where alder grows, and is most frequently seen where roads cross some little alder-lined stream or are carried by an embankment over marshy ground fringed with alder bushes. It is consequently a very local insect, and apparently rarely wanders more than a few rods from its birthplace.

In the Connecticut Valley it is recorded as being found about small running streams and in places protected from the wind, and at Norway, Me., as "resting upon the leaves of trees and bushes growing along the banks of a river."

Abbot said that in Georgia it frequents swamps and oak woods, and is most frequent in Big Ogechee swamp.

In West Virginia Mr. W. H. Edwards found the butterfly generally up the branches of the creeks in the valleys between lofty and abrupt hills flying about the stones in the nearly dry beds. In one day, on July 4, 1868, he caught no less than 24, and on this occasion the butterflies persisted in visiting a large stone and were so tame that he caught most of his specimens in a bottle. He adds that, so far as he knows, there were no alders within a mile of the point where the butterflies had been abundant. There were plenty of beeches, and he remarked that the probability is that any trees or shrubs on which there is a good supply of aphids would attract the females.

In my experience this species flies with the greatest activity and in the greatest numbers on hot and sunny days. It is most active from about 10 o'clock until about 3, when it seems suddenly to disappear. When at its best among the alders this is not at all an easy butterfly to catch. The flight is rapid, nervous, and highly irregular, with frequent rests. As it dodges and skips about among the alder branches it suggests a small and very active satyrid of the *Satyrodes canthus* type. Its flight about the exterior of the alder thickets has been compared to that of *Orgyia antigua*, and I have sometimes confused it with the males of gypsy moths. If badly frightened it flies off very rapidly in an irregular spiral, the axis of which commonly rises at an angle of about 30°. From this it would seem that its general habit is much like that of the species of *Gerydus*. It is very fond of flying up and down paths through alder thickets or through the near-by woods.

On three occasions I have met with this butterfly in open ground a very considerable distance from any alders or other source of food. The insects were flying slowly in a straight line a foot or so above the grass tops and showed no inclination to rest. All three were easily

caught. Their flight was wholly different from the normal flight of the species, and indeed from that of any other of our lycænids, but suggested that of the species of *Spalgis*. Two explanations suggest themselves: First, that the butterflies had been blown away and lost and were trying to discover a food supply; and second, that they represented a special variety characterized by this unusual type of flight and adapted for disseminating the species. The strong continuous flight would seem to negative the first alternative. The probability is that these individuals were "travelers," corresponding to similar individuals developed in many other species where, however, they commonly show departure from the normal in color as well as in the type of flight.

Mr. Scudder quotes Mr. Emery as saying that this butterfly is never to be seen about flowers, but may sometimes be seen perched upon the upper surface of a leaf, or, more commonly, upon a branch of alder among the woolly plant lice enjoying with the ants the honey exuding from their bodies.

I have noticed that when resting this butterfly seems to prefer to sit upon the upper side of horizontal leaves of willows or other trees or bushes rather than upon the leaves of alder. When upon the alder leaves or stems or upon the aphids it seems to be always nervous and alert, ready to fly off at the slightest hint of danger. It always sits upon the leaves head outward, with its tail turned toward the inner portion of the tree or bush.

Broods.—Mr. Scudder wrote that the first brood of butterflies of the year appears in New England about the beginning of the last week in May, and continues upon the wing until after the middle of June. The second brood appears early in July and becomes abundant by the middle of the month. Search at Granby, Mass., on July 28 brought to light only caterpillars in the second stage; a fresh specimen and full-grown larva were taken by him as far north as Sudbury, Ontario, on July 13, showing that even there the second brood appears at this early date. Fresh specimens may be found during the whole of July, and rubbed ones during August. Mr. Fletcher found a much-worn female ovipositing at Ottawa on August 2, and they continue upon the wing until the third brood appears, about the middle of August, from which time fresh specimens continue to come out until the end of September.

In the central region of its distribution there are, according to Mr. Scudder, probably four broods. Mr. Edwards recognized three in West Virginia, one from April 17 to May 5, the second from June 14 to July 4 (on this latter date he took 24 in 1868 and saw large numbers more), and a third the last of July. Mr. Scudder notes that when compared with the history farther north and considering

the longer season in the south this must indicate a fourth brood not observed by Mr. Edwards, who mentioned that he had received caterpillars from Washington, D. C., as late as October 4. Mr. Scudder surmised that it is probable that there is an added brood in the south, for Abbot records a caterpillar in Georgia as changing to a chrysalis on April 14, which indicates a parent on the wing in March, at the opening of the spring, and so an entire brood in advance of the valleys of West Virginia.

As remarked by Mr. Scudder, the winter is probably passed in the chrysalis, but it is not impossible, as conjectured by him, that it may also winter as a butterfly, for battered specimens have been taken on the wing very early in the year before the complete unfolding of the leaves.

Oviposition.—The female butterfly, as observed by Miss Morton, flutters about and finally settles on the aphids, carefully selects a place in the midst of them, and deposits an egg, always on the underside of the twig. Mr. Fletcher confirmed this observation, and noticed that the female runs all over the clusters of aphids with a twitching walk something like a wasp.

While the eggs are usually deposited in the mass of aphids, both Miss Morton and Mr. Fletcher noticed that they are sometimes laid on the bark near the aphids and occasionally on adjacent leaves.

I have watched two females placing eggs on the bark on the under side of the twigs just below the aphid clusters, an inch or so away. In these instances the exudation from the aphids was so very copious that I imagine the butterfly was deterred from alighting upon them. In both cases the females fluttered close to the patches for some minutes before suddenly alighting just beneath them.

Eggs.—The eggs are easily found by brushing off the aphids from the branch. There may be a dozen or more in a single colony of aphids, but in that event they are probably laid by several females. Miss Morton saw two females lay three or four eggs, and from one to four caterpillars of the same size is the usual complement for each aphid colony on alder. But later in the summer where the butterflies are common there may be a dozen or so caterpillars of all sizes from the very smallest to the fully grown in a large cluster.

As described by Mr. Scudder the eggs, which are much flattened and twice as broad as high, are faint green, almost colorless, and glistening. During deposition they are covered with a thin albuminous deposit which makes it difficult to get any proper view of their texture. Their surface is smooth and glistening, though still very faintly punctulate, broken up by very slight, slender, and equal rounded elevations into polygonal cells the height of which is a little greater than the width. They are very different from the usual type

of eggs laid by the Lycænidæ, which are covered with an elaborate and conspicuous lacework, or are much sculptured.

The first larval stage.—The eggs hatch in three or four days. The young caterpillars in the first stage are very different looking creatures from the fully grown. They are of a slightly greenish white with the head and legs more brownish, cylindrical, with the segments slightly swollen, and the head as broad as the body, obovoid, but produced at the mandibles. The hairs, which are as long as three segments, are disposed, as remarked by Edwards, very much as in some of the nymphalids, say *Polygonia* or *Phyciodes*.

As described by Edwards the young larva pushes its way under the large aphids, or in the case of such as are found on the plum and willow among them, and immediately begins to spin for itself a loose web, not close enough to conceal it from view were the aphids away, but sufficient to keep the aphids from walking over the body and to protect it when the molt is approaching and the skin is sensitive. The web seems to be just about the length of the larval hairs from the body. The aphids may be seen running over it, and often get their legs fast in the meshes and are very apt to be devoured as a consequence.

The second larval stage.—The first stage lasts about two days, when the little caterpillar molts. After this first molt the body is not so cylindrical, being somewhat flattened on the back and broadest in the middle. As described by Scudder the body is pale mouse brown, the hairs and papillæ black. The hairs are nearly as long as the width of the body at the extremities, slightly curved, and tapering with extreme regularity to the finest possible point. They are mostly arranged in a single somewhat sinuate and not entirely regular transverse series a little in front of the middle of each segment. Edwards describes the hairs at this stage as numerous, disposed in six rows, two subdorsal, one along the middle of each side, and one along the base of each side. They stand not in tufts, but in groups which spring from low tuberculous swellings. The hairs along the lower edge of the sides point downward and fringe the body.

The length of the caterpillar has increased from 1.6 mm., the length on hatching, to 5 mm. It still remains within the loose web underneath the aphids, but its presence can now be detected by a slight elevation in the otherwise uniform cylinder of aphids about the alder stem.

In the first two stages the caterpillars eat the aphids from underneath, burying their heads completely in the aphid's body. The long hairs on their upper surface entangle the woolly secretions of the aphids so that the little caterpillars appear as if covered with flour.

Miss Morton said that when these caterpillars molt they come out bright and clean, but by the time they crawl their own length they are again stuck over with wool, and this is the case until pupation.

The third larval stage.—After the second molt, which takes place about two days after the first, the body becomes higher and broader in the middle, and the hairs become more numerous. The feet and legs are not retractile. The head is more covered by the first segment than it was before, but it is only slightly covered, and that only along the forehead.

The fourth and last larval stage.—About two days after the second molt the third and last molt takes place. The body, as described by Scudder, is smoky pallid above with slender dorsal and laterodorsal smoky brown stripes, the former more or less interrupted, and both more or less tinged with olivaceous, especially in front, where the thoracic segments are more or less clouded between the stripes with olivaceous; more or less marked with pallid or whitish at the incisures and the posterior edge of the segments along the stigmatal and infrastigmatal lines. The hairs are mingled blackish and pallid, giving the whole a fuzzy gray appearance. Along the sides each segment has three or four more or less obscured blackish dotlike spots, especially an anterior laterostigmatal spot, and the fuscous spot in which the minute pallid spiracle is placed. Edwards says that the color of the dorsal area is pale gray, the outer edges white, and the side is white with a pale brown macular stripe running through it, and above this is an oblique brown bar on each segment, except at the extremities. In the middle of the back there is a macular brown stripe, and on the seventh-eleventh segments four brown rounded spots, two in front and two behind. The subdorsal swellings are red-orange, or Indian red, or pinkish. There is much variation in individuals in all the markings, and Mr. Edwards suspected that the species of aphis fed upon may cause variations, as one larva raised by him upon plum aphids was at all stages whiter than those on alder, and the darker markings pale.

These caterpillars are indeed very variable. They are usually grayish, somewhat tinged with greenish in front, ranging from very light to fairly dark. The reddish markings especially vary from deep dull brown to brick red or pink. Sometimes there is no brownish or reddish color at all, all the markings being gray. Occasionally the entire caterpillar is of a uniform pale pink. This variety is very rare on alder; but my son, Austin B. J. Clark, found five on a patch of woolly aphids (*Neoprociphilus attenuatus*) on a stem of the carrion flower (*Smilax herbacea*), all of which were of an immaculate pink. The pupæ and the adults from these were of normal coloration. Frequently on alder the white is more or less

tinged with pinkish, and the gray markings become more restricted and fainter. At this stage the caterpillar is 11 mm. in length.

The mandibles of the fully grown caterpillars are curious in being scarcely tapering, and in having the rounded apical margin armed with four curving clawlike teeth.

Miss Morton found the larvæ after the second molt crawling naked on the limb seeking for fresh supplies of food; she says that then they again spin a web which they leave after the aphids are consumed. She believed that they do not spin a web after the third and last molt; at this stage they go about very quickly.

Much depends, I believe, upon the size and vigor of the aphid colony. While the fully grown caterpillars are often seen resting in the aphid colonies with the whole dorsal surface exposed, and usually comparatively, sometimes entirely, free from wool so that their handsome markings stand out conspicuously, they may be more or less embedded in the aphids: and frequently, noticing large humps on the surface of the aphid mass. I have dug out fully grown larvæ from flimsy tunnels. Mr. Scudder noted also that some which he obtained remained in the web until ready to change into the chrysalis. Except for those just hatched and entering the aphid mass I have seen none but almost or quite fully grown caterpillars exposed, and I think that normally they do not leave their webs until they are ready to pupate. Even though they may not make a covered tunnel I believe the large caterpillars normally and usually spin a path of silk upon the twig as they plough their way through the aphid mass.

These larger caterpillars are very voracious, and a few of them will soon clean out all the aphids in an average alder colony. Where they are common there are always many characteristic ragged white or grayish patches on the twigs composed of the dead remains of aphids entangled in sparsely woven silk, with ragged streamers of silk and dried aphid bodies depending from it. In one locality in Weston, Mass., I observed a number of alder bushes upon which all the numerous aphid colonies had been quite exterminated by these caterpillars.

Mr. Edwards noticed that whenever one of these caterpillars was removed by the forceps a thread held it to the object on which it was resting. He shook his largest caterpillar out of the box until it let out a thread up to a length of 4 inches. Then he held the box to see if the caterpillar would climb the thread, which it did, in about 20 minutes. It twisted its body into a spiral and whirled about so fast that he could not bring the lens to bear, but he could see that the jaws and feet were active.

I have never seen fully grown caterpillars do this. When disturbed they curl up and drop directly down. Small or medium

sized caterpillars, however, drop on a thread, and this is usual until they are nearly of full size.

Miss Morton said that after the third molt the caterpillars go about very quickly. They crawl steadily and fairly rapidly when removed from the aphids; but in a vigorous aphid colony they are extremely sluggish, and I have rarely seen them elsewhere.

I have never observed any tendency on the part of *Feniseca* caterpillars to eat each other, even when scores of various sizes were confined without food in the same small box. In spite of their delicate skin the caterpillars are well protected by their long and partially grouped hairs, especially by those along the lower edges of the sides, which bend downward and prevent attacks from underneath.

But while the caterpillars seem to pay no attention to each other, my son, Hugh U. Clark, discovered that the smaller caterpillars not yet fully fed eagerly devour the freshly formed pupæ. These they attack from the under side, tearing a large ragged hole in them and completely devouring all the soft parts.

Rapidity of growth of the caterpillars.—Mr. Edwards noted that the growth of these caterpillars is remarkable for its rapidity, scarcely more than two days between molts, and there are but three molts in all. There is no long interval preceding a molt when the larva lies helpless, and this is particularly so at the third molt when the larva is fully exposed to view. He watched several most carefully when he anticipated the third molt, but was never able to see it, or to know precisely when it occurred. He could see that a molt must have taken place by the fresh and differently colored skin of the body and the enlarged head.

Miss Morton at first experienced the same difficulty. She wrote on August 30, 1886: "Thursday morning the larvæ had devoured every aphis in the box, and I remembered seeing some red aphids on wild cherry near the house. These I put in until I could go to the swamp a mile away. When I returned, three hours after, three of the five larvæ had molted, after eating nearly the whole of the 2 square inches of aphids, though there was no appearance of a molt when I went away." These three pupated Sunday morning, three days after the third molt.

The pupal stage.—About three days after the third molt the caterpillars pupate. Just where this takes place in a state of nature has not been satisfactorily determined. Miss Morton never found a chrysalis, although she looked for them whenever she was in the swamps. Her captive larvæ generally sought a leaf, but she thought it probable that the wild ones crawl down the stems and pupate among sticks or grass.

From the frequent occurrence of bare oval patches in aphid colonies inhabited by these caterpillars and the fact that when fully grown they curl up and drop at the slightest touch, while if aphids are abundant they are never found, in my experience at least, except in aphid colonies, I feel sure that the normal habit of the caterpillars on reaching full size is to drop to the ground and to pupate on any convenient support.

I have found two pupal skins from which the butterflies had emerged. One of these, in Newtonville, was about 4 feet up on the main trunk of a large alder which had no aphids on its branches; the trunk was about 3 inches in diameter. The head of the pupa was directed downward. The other, from Essex very near the Manchester line, was on the upper side of an alder leaf about a foot from the ground and directly beneath a large colony of aphids about 6 feet above it. The leaf was smeared with the exudations from the aphids to which cast skins and "wool" adhered. The pupa was in the inner half of the leaf and was attached to one of the veins near the midrib; its axis was parallel to the vein and its head was directed outward toward the margin of the leaf. In both these cases the larvæ had evidently dropped and thence crawled up to the supports on which they were found.

My experience with a dozen or so caterpillars that escaped in the house was quite similar to that of Misses Soule and Eliot. They pupated anywhere, one behind a picture 6 feet from the floor; but the favorite place was on the mop board or on chair or table legs from 2 to 6 inches from the floor.

As described by Mr. Scudder the chrysalis is pallid-green beneath, flecked with minute brown dots on the wings, legs, and tongue, but not on the antennæ, and hardly at all on the abdomen, excepting laterally. The head and prothorax are pallid, the former flecked with blackish, and the latter with many brownish flecks next to the posterior margin. The rest of the thorax is dark greenish-brown above, irregularly blotched and flecked with cream-yellow, most conspicuously at the summit and down the interior base of the wings. The rest of the wings is pallid-green, minutely flecked with brown. The abdomen is also dark greenish-brown, the first two segments darker than the rest and deepening to black laterally next to the wings, the whole irregularly flecked above with cream-yellow, giving a minutely mottled appearance, and at the sides of the globose portion and on the top of the expanding tip predominating; particularly the lower half of the sides of the fourth abdominal segment are almost wholly cream-yellow, and those of the sixth and seventh heavily blotched with piceous. There is a lateral series of short oblique black bars in the middle of the

second to seventh abdominal segments, and the tubercles and the median carina are all tipped with brownish-yellow. The surface of the body is rather coarsely and distantly punctate, with scattered, pellucid, clubbed hairs arising in large measure from the center of the pits, and but little longer than their widths. The spiracles are testaceous.

Mr. Scudder gives the following measurements: Length, 8.5 mm.; width at the middle of the thorax, 3.65 mm.; at the widest part of the abdomen, 4.75 mm.; of the tip of the abdomen, 2.5 mm.; height of the thorax, 3.6 mm.; of the abdomen, 4.2 mm.; length of hairs, 0.04 mm.

As was first noticed by Miss Morton, the chrysalis of this butterfly shows a most curious resemblance to a monkey's face (fig. 1).

FIGS. 1–5.—A pupa of the alder butterfly (*Feniseca tarquinius*). Fig. 1, viewed from above with the head (lower) end slightly raised; Fig. 2, viewed from above when lying flat; Fig. 3, lower surface; Fig. 4, side view. Fig. 5, The alder butterfly, natural size; the colors are black and bright brownish gold. Drawn by the author from a specimen hatched in Washington, but raised to the pupa stage in Newtonville, Mass.

Duration of the pupal stage.—The butterfly ordinarily emerges in from 8 to 11 days after pupation, according to Mr. Scudder. Edwards reared a caterpillar from the egg to the pupa in 10 days. Allowing 3 days for the period between the laying of the egg and its hatching, and 8 days from the formation of the pupa to the emergence of the adult, this would give a total length of development from the egg to the adult butterfly of 21 days, or 3 weeks, a most extraordinarily short period.

My experience with this butterfly has led me to believe that while the duration of life from the egg to the pupa is always brief as described, the length of the pupal life is very variable.

On August 14, 1923, at Newtonville, Mass., about 50 caterpillars pupated. On August 22, 12 adults emerged. A day or two after the first 50 pupated all of the remainder pupated, about 50 more.

By the middle of September all but 53 had emerged. These 53 pupæ were brought to Washington and from them butterflies continued to emerge at irregular intervals all through the winter and spring, sometimes two or three a day. The last to emerge did so some time subsequent to July 7, on which date I left Washington. Thus from the same lot of pupæ dating from the middle of August, butterflies emerged continually up to the end of the first week in the following July, for very nearly 11 months, the chrysalids having all been kept in the same box in a heated house. Only one chrysalis died, and that was less than half the normal size.

In the summer of 1924 the caterpillars were very scarce. Fifteen secured in Essex, Mass., pupated on and about September 1. These were brought to Washington about the middle of the month, and the butterflies emerged at irregular intervals from December to April. The last failed to spread its wings, the one preceding did not spread its wings completely, and one has not as yet (May) appeared.

All of the butterflies which emerged in Washington differ from those caught or raised in Massachusetts in having the black markings on the forewings more restricted, presumably through the pupæ having been kept at a temperature above the normal for them.

Food of the caterpillars.—The large white woolly aphis of the alder (*Schizoneura tessellata*), which forms conspicuous snowy colonies, seems to be the chief and favorite food of the caterpillars of this little butterfly. But it has several times been found among the colonies of another aphis (*Pemphigus imbricatus*) on the beech, and in the leaf curls of a related species (*P. fraxinifolii*) on the ash. My older son found five in a colony of woolly aphids (*Meoprociphilus attenuatus*) on the carrion flower (*Smilax herbacea*) near a heavily infested alder thicket.

The caterpillars and the pupæ have been found on various plants, such as witch-hazel; but there is no certain evidence that normally they live on these.

In captivity the caterpillars will eat other kinds of aphids. Miss Morton found that they would eat the red aphids on wild cherry. Mr. Edwards put some aphids which he found on weeping willow in a tube with some young caterpillars. He watched for some time, but there was no haste on the part of the caterpillars. He saw one of them go to an aphid, nose at it, push it, and bite at it, lifting it partly off the leaf (the aphid being the larger of the two) and shaking it as a dog would shake a rat. But the victim escaped and retreated to the reverse side of the leaf and the larva rested. Next morning not an aphid was to be found. He obtained another small supply of willow aphids and presently saw a caterpillar bite one near the head and eat into the body so that its own head was buried, the aphid not resisting, not even removing its beak from the leaf.

After a moment the caterpillar let go and went its way. Not finding more aphids on willow, he searched many trees and shrubs in vain, but at last he found a young wild-plum somewhat infested with them and thereafter had a moderate supply.

Relationships with ants.—Miss Morton noted that there are four species of ants guarding the aphids on the alders, and she found fewest caterpillars among those guarded by a large kind with black head and abdomen and red thorax which swarms all over them for the sake of the exceedingly sweet liquid they exude. The ants do not let the caterpillars alone, biting at them furiously whenever they see them; but until nearly fully grown the larvæ lie concealed under the aphids with a web covering them and can not be reached without disturbing the aphids.

One morning she found what she thought was a full-grown larva. It was resting in a fork of the bush close to a large colony of the aphids; but while she was wondering how she should get it in her box the way was suddenly made plain by a large ant rushing at it and biting it furiously.

Once she came across a place where the large black and red ants were in a state of great excitement, running and biting in every direction, and had probably just discovered and routed a full-grown larva, as a large brown spot with all the aphids cleared off showed itself on the limb. I believe that this interpretation is not quite correct. It is more likely that the brown spot represented the previous location of a fully grown larva which had finished feeding and dropped to the ground to pupate, and that the ants were annoyed at the discovery of the gap in the aphid colony.

Mr. Scudder stocked with aphids an alder he had planted for the purpose in his garden, and on July 31 placed there a caterpillar in the second stage. The aphids were all small, and in two large clusters. The caterpillar moved about over the lower colony for an hour or more, apparently looking for a good place to push under it, and he observed its contact with the ants on 20 or 30 occasions. They tickled it with their antennæ and it remained at such times absolutely quiet, generally moving off when they left in the opposite direction to that in which it had been touched. They offered it no further attack. Having to leave for an hour, he found on his return, just at nightfall, that the caterpillar had quitted the lower colony for the upper, 6 to 8 inches distant up the stem, and the same process was repeating with the ants there. The next morning it was found dead beside the colony, the outer edge of which it had eaten and removed, its body bitten just in front of the middle on each side in two or three places. The colony was composed of individuals too young to burrow under, and being unable to conceal itself it had fallen victim to the ants, then victoriously nursing their colony.

Mr. Edwards experimented amongst aphids on willow and plum, all small and naked species, with three caterpillars in the second, third, and fourth stages that he had received from Miss Morton. He laid the smallest larva on a willow leaf directly by a small cluster of aphids at which a few ants were engaged. The caterpillar paid no heed to the aphids, but walked past and back and forth and was on both sides of the leaf. The ants were somewhat inquisitive, but did not trouble the caterpillar, nor were they disturbed by it. This went on for about 15 minutes, when he removed the larva.

He put the next sized larva (second molt) on the same leaves, and the ants were agitated and ran about gesticulating, but paid more attention to their cows than to the larva. He put this larva on a plum leaf by a large colony of aphids at which were a dozen black ants. The ants sprang at it, bit at it everywhere, especially trying to get a hold under the edge of the body where the surface is naked, or at the joints of the segments, or at the second segment which, being bent over the head, is more exposed than any other segment. One determined fellow seized on the second segment and was hardly to be dislodged, was at last by a violent jerking of the head, but wounded the larva so that blood flowed. When the attack was at the joints the larva squirmed so as to tighten the joints just there. These attacks were simultaneous and by at least six ants at a time. The larva crawled away, and the assailants mostly dropped off.

He then put the largest larva (third molt) amongst the same excited ants, and they attacked it in the same manner, but seemed unable to make an impression on it. The hairs protected the whole upper side more sufficiently. The caterpillar crawled up and down over the leaf, followed by some of the ants which attempted to seize it at every vulnerable part. But no harm was done. He repeated the experiment the next day and came to the conclusion that the willow ants were mild tempered, and seemed unlikely to hurt a larva; but that the black ones were fierce and would attack whenever they saw the enemy.

He suggested that perhaps the butterfly avoids the fiercer ants and the aphids which they guard, and, therefore, is not to be looked for on certain plants.

Though exhibiting great hostility toward the caterpillars the ants do not destroy the eggs. The butterflies do not pay any attention to the ants, nor do they disturb them.

Enemies.—So far as is known this butterfly has no parasites, and nothing is known to feed upon it.

Once with a knife blade I was dislodging a fully grown caterpillar from a mass of aphids when it was struck by a large reduviid

bug (*Arilus cristatus*) which up to that time I had not noticed. It dropped at once into my box apparently quite dead. Mr. Charles O. Farquharson wrote that in Southern Nigeria he saw one of the brown hairy moth-like caterpillars of the lichen-feeding lycænid *Epitola honorius* attacked and killed by a reduviid bug (*Sphedanolestes*, sp.).

Associates of the caterpillars.—On the alders two others insects are commonly found with the larvæ feeding on the aphids, and sometimes a third. Most common is the larva of a lace-winged fly (*Hormosoma*, sp.), which is about the size of a full-grown aphid. This creature has the habit of covering its back with aphid wool and skins so that if it remains quiet it is scarcely to be distinguished from them. It is, however, rather active, and as the aphids are quite inert anything that resembles an aphid running about is to be regarded with suspicion. Examination with a glass will reveal the two enormous mandibles characteristic of the lacewing larva. I have never seen this insect attack a caterpillar.

Almost as common as the young lacewings are the grayish headless and legless grubs of a syrphid fly (*Syrphus*, sp.). These lie under the aphids, often in a web made by the caterpillars, and are difficult to find. According to Miss Morton these grubs stick the wool from the aphids on their own backs and are often difficult to detect. When fully grown they are frequently naked and are then quite conspicuous. Miss Morton relates that she watched a little caterpillar just out of the egg spinning a web close to and almost under a large syrphid grub, so she supposes that these grubs do not injure the caterpillars. The little caterpillar crawled under the mouth of the grub and over its back without the least notice being taken by it. Miss Morton noticed that these syrphid grubs devour the aphids far faster than do the caterpillars.

The ants take not the slightest notice of the young lacewings nor of the syrphid grubs, even though the latter are much more destructive than the caterpillars against which they display so much ferocity.

Lachnocnema bibulus

The larva of this species is much like that of *Megalopalpus*. It has no glandular apparatus. Mr. Lamborn found that although it is protected by coarse hairs the ants certainly treat it with more consideration than they show toward *Megalopalpus*, and in one case he gained the impression that they were endeavoring to feed it in spite of its habit of preying on their homopteron protégés.

The food of this species is the jassid *Ossana bicolor*, in every case found on similar food plants.

Mr. Lamborn saw the first larva he discovered passing its mouth to and fro over tiny homopterous larvæ as if it might be obtaining food, and he frequently saw the ants feed it with material obtained from the insect larvæ. An ant and a caterpillar stand in front of each other mouth to mouth. Some jerky movements take place, the ant stroking the larva with its antennæ after the manner of an *Œcophylla* ant which, having stored itself with water, proceeds to dispense it to its fellows.

After writing these notes he speculated as to whether he might not have been mistaken in thinking that the ants fed the larvæ. He suggested that perhaps the position is reversed, and it is the larva that provides the ants with food, possibly buccal secretion or regurgitated material, since it has no dorsal gland.

When he first had the larva it did not feed, as far as he could see, for 24 hours unless the ants gave it food, but it then ate a number of the jassids.

He suggested that these carnivorous larvæ when they find a colony of food insects have to make as big a meal as they can so as to be prepared against a possible long wait before they find others.

Mr. Charles O. Farquharson found a few larvæ of this species, with a very large number of membracids and a much larger number of ants, on a small leguminous shrub (*Cassia alata*) at the base of a palm. The larvæ, so far as he could see, are without honey glands or tubercles. They are rather bristly, with the head protected by the usual carapace. The color is a curious blend of the membracid color, with additions. In appearance they reminded him very much of certain large syrphid larvæ which he had seen eating aphids, and the latter resembled bird droppings more than anything else. The young larvæ are rather more bristly than the older ones, and less pronouncedly onisciform.

These larvæ made no attempt to eat the membracids, and the relation between the lycænid larvæ and the membracids was with the larval stage of the latter, which he saw as clearly as possible.

The lycænid larvæ are very sluggish in their movements, and all the time he remained hardly moved an inch. Whenever a membracid larva came near it got busy, and so did the ants. They all got busy in the same quarter, which was the upturned retroussé end of the abdomen from which, at fairly rapid intervals, a short process was thrust out on the tip of which a clear droplet was simultaneously visible and instantaneously mopped up by the most enterprising of the suitors, which was generally the lycænid in virtue of its superior size. Along with one or two ants it tickled with its anterior true legs the business end of the membracid, but by lolling in a gross and

unmannerly way right over the orifice it hardly gave the ants a chance. When an ant did get there first it generally shared by regurgitation the good thing with a fellow, and he was inclined to think on one or two occasions with the less gracious lycænid. But they showed no ill feeling if the latter got there first.

Later he saw another larva feeding on the droplet, but not on the membracids. But in an examination of the frass of others he found undoubted insect remains.

He noted that there is a suggestion of a monkey face in the pupa of this butterfly, but he thinks that, at a little distance off, the effect is much more of the bird-dropping order, in a different way from that of the larva, for the colors are those of brown paper and putty nicely blended.

Triclema lamias

At Moor Plantation, about 4 miles west of Ibadan, Southern Nigeria, Mr. Charles O. Farquharson came upon two lycænid larvæ which were slowly devouring a happy family of coccids (*Lecanium* [*Sasseta*] *farquharsoni*) on a plant of *Imbricaria maxima*. They were dull green, onisciform, with just a hint of a white line along the edge of the mantle and a slightly lighter mid-dorsal line. There was a gland, but Mr. Farquharson could not see any sign of tubercles.

Mr. Lamborn had previously found that the larvæ of the allied *T. lucretilis* are associated with coccid-tending ants, but did not think that they were carnivorous; he saw the larvæ eating the dark green cortex of a soft plant, but at some later stage they may, as suggested by Professor Poulton, have attacked the ant-tended coccids he found in tunnels in the same stems.

SUMMARY

The food habits of all the butterflies with carnivorous caterpillars represent merely an extension of the intimate association with ants which is eminently characteristic of the family to which they belong, for they all feed either upon the young of ants, upon material regurgitated by ants, or upon ant-tended insects.

In the Lycæninæ the great majority of the species are vegetarians, but with marked carnivorous leanings as evidenced by the common display of cannibalism. In the genus *Lycæna*, *L. arion* in the last larval stage turns upon the ants which up to that time have protected it in return for the honey it supplied them, and devours their young. The larvæ of *L. alcon* in the last stage similarly live on the juices of ant grubs. The ant-eating habit characteristic of the last stages of the caterpillars of *Lycæna arion* and *L. alcon* passes into the ant-eating habit of *Liphyra*, which gives no honey in return.

The larvæ of *Triclema* seem to be at first vegetarian, later feeding on ant-tended coccids. From this it is but a step to the habits of *Spalgis*, *Feniseca*, *Gerydus*, and *Aslauga*, the caterpillars of which feed all their lives on ant-tended aphids or coccids, and to those of *Lachnocnema* and *Megalopalpus*, which feed all their lives on ant-tended jassids and membracids.

Besides the natural transition of lycænids into carnivores feeding on ants and on ant-tended insects, there is the equally natural transition, seen in *Euliphyra*, into a form which induces ants to feed it.

There is no doubt that when the life histories of our western and southwestern and especially our tropical lycænids have been worked out other examples of carnivorous forms will come to light.

THE POTATO OF ROMANCE AND OF REALITY[1]

By William E. Safford

[With 12 plates]

The early history of *Solanum tuberosum* is obscured by conflicting stories, many of which must be relegated to the sphere of romance. In the United States, this plant is commonly called the "Irish potato"; but it is only a potato by analogy and Irish by adoption. The true or original potato is the *Ipomoea batatas* (pl. 2), which we now call "sweet potato," a plant belonging to the Convolvulus or morning-glory family; the "Irish potato" belongs to the Solanum or nightshade family, of evil repute, many of whose members have poisonous or narcotic properties. The name potato is scarcely more applicable to it than "pig" to guinea pig or "dog" to prairie dog, yet this is the only name by which it is known to English-speaking people. The French call it "pomme de terre," or earth apple; the Spanish "papas," its original name; the Germans "Erdapfel," "Erdbirne," "Grundbirne," or "Kartoffel," the last word a modification of "Tartuffel" or truffle.

THE POTATO OF ROMANCE

For the application of the name potato to *Solanum tuberosum*, as well as for the erroneous statements regarding its origin, the responsibility must be charged to John Gerard, who in 1597 figured and described it under the title of "Potatoes of Virginia—*Battata Virginiana sive Virginianorum & Pappus.*" His illustrations (fig. 1) and description show that his plant was, indeed, *Solanum tuberosum*, but he follows his description with the statement that "it groweth naturally in America, where it was discovered, as reporteth C. Clusius; since which time I have received roots thereof from Virginia, otherwise called Norembega, which growe and prosper in my garden, as in their own native countrie."[2] To this he adds "the In-

[1] Reprinted by permission, slightly abridged, from The Journal of Heredity, Vol. XVI, No. 4, April, 1925.

[2] The Herball or General Historie of Plantes, gathered by John Gerarde of London, Master of Chirurgerie. p. 781. 1597.

dians call it 'Pappus,'" an assertion which would lead one to believe that it was thus called by the Indians of Virginia. In reality the name "papas" was its vernacular name not in Virginia, but in

FIG. 1.—The first published illustration of *Solanum tuberosum*. This appeared in Gerard's Herbal in 1597 under the misleading name *Batata virginiana*. Nine years earlier, Clusius, to whom Gerard refers, had received a drawing of this species from Philip de Sivry under the name *Papas peruanum*

Peru, which, as we shall see later, was its original habitat. As a matter of fact, the potato did not reach Virginia for more than 120 years after the publication of Gerard's Herbal. It must have been Gerard's statement which led Thomas Jefferson to declare

that "round potatoes" (*Solanum tuberosum*) were found in Virginia when first visited by the English.[3]

It is surprising that Jefferson should have made this mistake; for he may be called Virginia's historian, and he was especially interested in all things pertaining to food plants and their culture. Still more surprising is the mistake of Schoolcraft, one of our most reliable authorities on the history and customs of the American Indians. In an official report published by the State of New York in 1846 he makes the following statement: "The potato was certainly indigenous [to America]. Sir Walter Raleigh in his efforts at colonization had it brought from Virgina under the original name of 'Openawg.' But none of the North American tribes are known to have cultivated it. They dig it up like other indigenous edible roots from the forest, but it has long been introduced into their villages and spread over the northern latitudes, far beyond the present limit of Zea maize."[4]

The persistence of erroneous stories regarding the potato is shown in the following quotation from a recent standard work of reference, under the heading potato, "commonly known as the 'Irish, white, or round' potato." "It seems to have been introduced into Europe as early as 1565. Sir Walter Raleigh in 1585 is said to have brought back the potato from a new country. Recent investigations, however, seem to give the credit of introducing the potato into England to Sir Francis Drake in 1586. As *Batatas Virginiana* it was figured and described by Gerard in 1597. It is probable that these circumstances led erroneously to giving the credit of introducing the potato to Raleigh instead of to Sir John Hawkins." And farther on in the same work, where it is assumed that the potato is really identical with the openawk of Virginia, appears the following: "The tubers of the wild *S. tuberosum* were small and attracted little attention. Heriot, in his Report on Virginia, describes one plant 'with roots as large as a walnut and others much larger. They grow in damp soil, many hanging together, as if tied on ropes.' The modern potato has been bred so that the hills contain four to six tubers of uniform size, weighing perhaps 2 pounds."[5]

In a publication of more recent date appears the following: "In 1565, Hawkins found potatoes at Santa Fé de Bogotá and carried some thence. * * * It is quite possible that Hawkins carried the potato to North America in 1565, when he relieved the famine among the French on the banks of the River May, now St. John's,

[3] Jefferson's Notes on Virginia, in Writings of Thomas Jefferson, 8:225. 1884.

[4] Schoolcraft, H. R. Census of the Iroquois. New York State Documents, No. 24. p. 12. 1846.

[5] Bailey's Standard Cyclopedia of Horticulture, 5:2767, 2768. 1916.

Florida, and sailed northward towards Virginia, where, in 1584, Heriot describes under the name Openawk what is supposed to be the potato." [6]

Now, it is quite certain that Sir John Hawkins never visited Santa Fé de Bogotá. Had he done so he might indeed have encountered *Solanum tuberosum*. On referring to his original narrative I find that in 1565, on his first voyage, his ship, the *Jesus of Lubeck*, went for water and provisions to a port called Santa Fé on the coast of what is now Venezuela. There he received from Carib Indians—naked savages who slept in cotton hammocks and were armed with poisoned arrows—"hennes, potatoes and pines." The "hennes" were an indigenous pheasant-like bird commonly called "curassow," which the Indians of that region still domesticate. The "pines" were pineapples "of the bignes of two fistes," the inside of which "eateth like an apple, but is more delicious than any sweete apple sugared." The "potatoes" were what we now call sweet potatoes, "the most delicate roots that may be eaten." These were, after manioc (the roots from which tapioca is derived), the most important food staple of the Indians inhabiting the islands and shores of the Caribbean Sea, a region where *Solanum tuberosum* was quite unknown at the time of Hawkins' visit. Sweet potatoes were encountered by Columbus and his companions immediately after their arrival in the New World and were highly esteemed, not only for their delicious taste but for the ease with which they could be propagated and their immunity from the hurricanes which so frequently destroyed the plantations of upright manioc. Columbus never saw a tuber of *Solanum tuberosum*, nor was this plant encountered by Cortez in Mexico.

The identity of Sir John Hawkins' potatoes was recognized by Sir Joseph Banks, who called attention to the fact that the sweet potato was introduced at a very early date into the Canary Islands and Spain, whence it was imported in considerable quantities into England long before the introduction of *Solanum tuberosum*.[7]

The openawk of Virginia, with which the potato was also confused, was described in 1588 by Thomas Heriot, the historian of Sir Walter Raleigh's second ill-fated colony on Roanoke Island, who published the first accurate account in English of North American Indians and their food-plants. It is quite certain that he never carried a tuber of *Solanum tuberosum* from Virginia to

[6] Sturtevant's Edible Plants. Edited by U. P. Hedrick, in Report of the New York Experiment Station, New York State Department of Agriculture, 27th Annual Report. Vol. 2, part 2, p. 546. 1919.

[7] Banks, Sir Joseph. "An attempt to ascertain the time when the potato (*Solanum tuberosum*) was first introduced into the United Kingdom." Transactions Horticultural Society of London, 1: 8–11. 1805.

England. His openawk was not a Solanum, but *Glycine apios*, a tuber-bearing leguminous plant not even remotely related to the Solanaceæ.

The tubers of *Glycine apios* were an important food staple of all the Indian tribes of eastern North America from the Gulf of Mexico to the St. Lawrence River. By the English colonies they were called Indian potatoes, bog potatoes, or ground nuts. By the settlers of New France they were called "chapelets," or rosary roots, from their bead-like arrangements on strings. The various tribes of Indians had each its vernacular name for them. "Openawk," "openaug," "penag," or "penac," were their Algonquin names.

This name has come down to us in a variety of forms, according to the orthography of early writers. Strachey, in his account of the Jamestown Indians, called it "ouhpunnauk"; according to Zeisberger, its Delaware name was "hobbenac"; Peter Kalm gives its diminutive form "hopnis" (*hopenis*), which may be translated "those small roots." At the time of his visit the Swedish colonists still called it by its Indian name. In his description of the plant he says: "The roots resemble potatoes and were boiled by the Indians, who eat them instead of bread. Some of the Swedes at that time likewise ate this root for want of bread. Some of the English still eat them instead of potatoes. Mr. Bartram told me that the Indians, who live farther in the country, not only eat these roots, which are equal in goodness to potatoes, but likewise gather the peas which lie in the pods of the plant and prepare them like common peas."[8]

In early accounts of the settlement of New England these potatoes, called ground nuts, were the chief reliance of the colonists in times of scarcity. In the personal narrative of Mrs. Mary Rowlandson, the wife of a clergyman, taken captive by the Indians during King Philip's War, she refers frequently to ground nuts, which she characterizes as the principal wild food staple of the Indians.[9] They were eaten either boiled, roasted, made into cakes, or added to broth of meal made of the bark of a tree.[10]

The Abbé Provancher[11] gives the Quebec name of the ground nut as penac, without the prefix. The early missionaries of New France,

[8] Kalm, Peter. Travels in North America. London. 1772. See Pinkerton's Voyages, 13: 533. 1812.

[9] "Their chief and commonest food was ground nuts; they eat also nuts and acorns, artichokes, lily roots, ground beans [*Falcata comosa*, now usually called hog peanuts], and several other weeds and roots that I know not."—Narrative of the captivity of Mrs. Mary Rowlandson, wife of the Rev. Joseph Rowlandson, who was taken prisoner when Lancaster (Mass.) was destroyed in the year 1676; written by herself. In Indian Captivities, by Samuel G. Drake, p. 54. 1851.

[10] Op. cit., p. 38.

[11] Provancher, Abbé L. Flore Canadienne, 154. 1862.

like the settlers of New England, were obliged to resort to the roots when provisions were scarce. It is related that in the winter of 1613 Père Biàrd, with two companions, went in search of them in the woods near Port Royal. In the narrative it is stated that the roots were quite abundant in some localities, yet scarcely a patch could be found where the savages had not already been digging them, so that most of those they got were small, "and it was necessary to work pretty hard to gather enough for a day's living."[12]

Glycine apios of Linnæus, or *Apios tuberosa*, as it was called by Moench, is a twining, beanlike plant with alternate pinnately compound leaves composed of five to seven leaflets and dense racemes of small purplish brown papilionaceous flowers having a broad reflexed standard and an incurved keel. The pod is a linear, slightly curved, many-seeded legume. The tubers, aptly described by Heriot in 1588, "are a kind of roots of round forme, some of the bignes of walnuts, some far greater, which are found in moist and marish grounds growing many together one by another in ropes, or as thogh they were fastened with a string. Being boiled or sodden they are very good meate."[13]

In the accompanying illustrations, Plate 3 is the photograph of two flowering branches twining about a grapevine (natural size). It was collected in a "marish" thicket in Virginia, July 31, 1923, by Mr. O. M. Freeman, of the Bureau of Plant Industry. Plate 4 is a clump of rootstocks from a single plant, with the tuberous swellings "growing one by another in ropes, or as though they were fastened together with a string." It was collected in Takoma Park, near Washington, D. C., November 13, 1915, by Mr. J. B. Norton.

The confusion between the openauk of Virginia and the papas, or *Solanum tuberosum* of Peru can be traced to Clusius, who did not suggest that they were identical, but, in a description of the potato, published in his History of Rare Plants, after calling attention to the tubers called "papas," observed by Pedro de Cieza de Leon at Quito, he adds that those roots which the Virginians called "Openauk" were apparently not very unlike them.[14]

Clusius was referred to by Gerard as though he were responsible for identifying the Peruvian papas with the Virginian openawk. So

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[12] Biàrd, Rev. Pierre. Relation de la Nouvelle France, p. 213. 1616.

[13] See "A briefe and true report of the new found land of Virginia; of the commodities there found and to be raysed, as well merchantable, as others for victuall, buildiag and other necessarie uses for those that are and shall be planters there; and of the nature and manners of the naturall inhabitants. Discovered by the English Colony there seated by Sir Richard Grenville Knight in the year 1585 . . . at the special charge and direction of the Honorable Sir Walter Raleigh Knight, etc. . . . Directed to the Adventurers, Favourers, and Welwillers of the action, for the inhabiting and planting there. By Thomas Heriot, servant of the above-named Sir Walter, a member of the Colony, and there employed in discovering. Imprinted in London, 1588."

[14] "Quibus non valde absimiles videntur eae radices, quas Virginienses Openawk nominant." Caroli Clusii, Plantarum Historia liber quartus, p. LXXX. 1601.

proud was Gerard of possessing this plant that he caused a portrait of himself to be engraved with a flowering branch of it in his hand. This portrait (pl. 1), bearing the date of 1598, was inserted at the end of the preface to his celebrated work.

Gerard's misleading statement regarding the source of his potatoes has been discussed by several writers interested in the origin of cultivated plants. It has been suggested that his illustration of *Solanum tuberosum* may have been prepared on the Continent, like many of the other engravings in the Herbal,[15] and it has even been intimated that he concealed the real origin of his tubers in order to "mystify the readers of his Herbal."[16] Whatever may have been his motive, the effect of his account of *Solanum tuberosum*, described and figured under the name "Battata virginiana," or Virginia potatoes, was to fasten upon a Peruvian plant an English name already belonging to a very distinct species and to mislead posterity into the belief that *S. tuberosum* had been brought to England from Virginia. The persistence of this error has already been noted. One of the writers above referred to, assuming Heriot's openawk to be the potato, quotes his statement that its tubers were found in "moist and marish grounds," notwithstanding the fact that *S. tuberosum* will not grow in moist situations, nor do its tubers resemble those of *Glycine apios*, which "grow side by side, like beads on a string." Indeed there is no species of tuber-bearing Solanum indigenous to eastern North America; yet the woods are still full of Heriot's openawk.

Among the earliest legends relating to the potato is that recorded in the minutes of the Royal Society of December 13, 1693, in which it is set down that Sir Robert Southwell, the president of the society, claimed that potatoes were brought into Ireland by his grandfather, who first had them from Sir Walter Raleigh. "This evidence," says Sir Joseph Banks, who seems to have accepted the statement as true, "proves not unsatisfactorily that the potato was first brought to England either in the year 1586 or very soon after, and sent from thence to Ireland without delay by Sir Robert Southwell's ancestor, where it was cherished and cultivated for food before the good people of England knew its value; for Gerard, who had planted it in his garden in 1597, recommends the roots to be eaten as a delicate dish, not as a common food;" and to this Sir Joseph adds "the name of the root in South America is papas and in Virginia it was called openawk."

The Raleigh legend can be traced to Doctor Wright of Edinburgh; it belongs in the same category with the story of George Washing-

[15] See W. S. Mitchell, in the Gardeners' Chronicle, N. S., 25 : 533, May 1, 1886.
[16] See B. D. Jackson, in the Gardeners' Chronicle, Third Series, 27 : 161, Mar. 10, 1900.

ton and the cherry tree. In the appendix to the report of the committee of the board of agriculture concerning the culture and use of potatoes is the following communication dated March 14, 1795: "In 1584 Sir Walter Raleigh, so celebrated for his worth, his valor, and his misfortunes, discovered that part of America called Norembega and by him named Virginia. Whether the admiral was acquainted with the potato on his first voyage or whether it was sent to him by Sir Thomas Grenville or Mr. Lane, the first governor of Virginia, is uncertain. It is probable that he was possessed of the root about the year 1586. He is said to have given it to his gardener, in Ireland, as a fine fruit from America, and which he desired him to plant in his kitchen garden in the spring." Then follows an alleged conversation between Sir Walter and his gardener, which was later attributed to Sir Francis Drake and his gardener, to be quoted below.

This transfer of the honor of introducing the potato from Raleigh to Drake was the result of investigators, who found that Sir Walter had not discovered Norembega, had never indeed been in Virginia, and that his unfortunate colony on Roanoke Island had been brought home by Sir Francis Drake. They did not, however, establish the fact that Sir Francis ever had a garden in Ireland or a gardener in any country. There is not a particle of evidence that Sir Walter ever saw a potato in America, and the only opportunity which Sir Francis Drake had to see one was in November, 1578, when after passing through the Straits of Magellan he turned northward and received some potatoes from the natives of Mocha, an island in 38° 30′ south latitude on the coast of Chile. From this place he continued northward, looting the coast towns of Chile and Peru, and then "sailing along the backside of America to 43° of northerly latitude," after which he returned to England across the Pacific and Indian Oceans, rounding the Cape of Good Hope, "the fairest cape we saw in the whole circumference of the earth."

Completing his "renowned voyage, the second circumnavigation of the earth," in November, 1580, he was honored by a visit from his sovereign, Queen Elizabeth, who dined with him on board his ship, the *Pelican*, but there is no record that potatoes appeared on the bill of fare. Indeed, it was not until eight years afterwards that he is alleged to have introduced the potato.

Following are the two legends, the second of which I have translated from the work of a German clergyman, Rev. Dr. Carl Wilhelm Ernst Putsche, published in 1819:

THE RALEIGH LEGEND

Solanum tuberosum, the common potato of our fields and gardens, was first introduced by Sir Walter Raleigh, who brought the roots from Quito and caused them to be planted in his own garden in Youghal, in Ireland. On the

plants arriving at maturity Sir Walter's old gardener, availing himself of the privileges of his situation, gathered some of the fruit, or "potato apples," as they are now called, and tasted them. Those of our readers who have eaten of this particularly unpalatable and unwholesome production will feel no wonder that the ire of the old man should have been raised. Breaking in unceremoniously on his master's studies he exclaimed: "If this is your fine foreign fruit, I would not give it garden room, not I." "Well," said Sir Walter," "if it is as bad as you say, dig it up at once; but if you find any roots worth looking at bring them to me." It is, perhaps, needless to say that the roots proved very well worth examining.

THE DRAKE LEGEND

The famous English admiral, Francis Drake, deserves the credit for the introduction of the potato into Europe. On his return from Virginia in 1586 he brought thence the potato with him. * * * Wishing to domesticate it in England, he not only gave some of the tubers to John Gerard but also handed a part of them to his own gardener, telling him to plant the precious fruit in his garden. * * * When the seed apples ripened the gardener tasted them and threw them away in disgust. Bringing a few of these apples to the admiral, he asked sarcastically, "Is this, then, the famous fruit from America?" The admiral replied with feigned gravity, "Very well, if you believe the plant to be worthless pull it up, roots and all, before it spoils the garden." The gardener did as he was bid; but to his surprise under each plant he found a considerable number of tubers of the same form as those he had laid in the earth the previous spring.

That the Raleigh legend was generally accepted as true is shown by Rev. Francis Mahoney in his celebrated Reliques of Father Prout, the frontispiece of which represents the first planting of the potato in Ireland with Sir Walter, pipe in mouth, as the central figure. Under the heading of "Father Prout's Carousal," the attention of Sir Walter Scott, who is represented as a guest, is called to the potato. In handing it to him Knapp, the mayor of Cork, makes the following speech:

Sir Walter, as it has been my distinguished lot—a circumstance that confers everlasting glory on my mayoralty—to have had the honor of presenting you yesterday with the freedom of the corporation of Cork, allow me to present you with our next best thing, a potato.

Sir Walter Scott:

I have received with pride the municipal franchise and I now accept with equal gratitude the more substantial gift handed me in this capital esculent of your happy country.

Father Prout:

Our round towers, Sir Walter, come from the east, as will one day be proved; but our potatoes come from the west; Persia sent us one, and Virginia the other. We are a glorious people. Two hemispheres minister to our historic recollections; and if we look back on our annals, we get drunk with glory. * * *

Sir Walter Scott:

I intend writing a somewhat in which Sir Walter Raleigh shall be a distinguished and prominent character; and I promise you the potato shall not be forgotten. The discovery of that root is alone sufficient to immortalize the hero who lost his head so unjustly on Tower Hill.

Father Prout may be excused from accepting this legend as gospel; for he was essentially a man of letters; but we find it to have been accepted also by a professional horticulturist in a monograph on the potato, a copy of which was kindly sent me by the distinguished authority on potato diseases, Dr. Otto Appel, Direktor der Biologischen Reichsanstalt für Land und Forst-Wirthschaft at Berlin-Dahlem. "Most assuredly," says the author, "do I think that the descendants of Raleigh might be proud of a sprig of potato foliage on their coat armor, as those of Appel de Kapoesang are of its tubers, with which the Austrian heralds have charged their shields."[17]

Sir Walter's fame has never been perpetuated in the manner suggested above. Worse than this, the credit for its introduction was transferred to Sir. Francis Drake and a monument to him was actually erected and still stands in the city of Offenburg, Baden, a photograph of which, received through the kindness of Doctor Appel, is herewith reproduced (pl. 5).

The persistence of potato legends among literary people of romantic temperament is not surprising. They would naturally resent the iconoclastic destruction of a good story; but it is remarkable that in very recent works dealing with agricultural history these tales should be taken seriously. I have already referred to the account of the potato published in a modern cyclopedia of Horticulture. Following is a quotation from a more recent work on the history of American agriculture under the heading "How potatoes were brought to England:"

Sir Francis Drake in 1584–86 conducted a piratical expedition to the West Indies. He captured several towns and cities and held each until its release was purchased by the inhabitants and also seized and plundered several Spanish ships. For some reason, either fearing capture by the Spaniards, if he returned to Europe by the usual route, or because of sickness among his men as think some authorities, he cruised up the Atlantic coast to return by a more northern route. He found the second Raleigh colony on Roanoke Island in a destitute condition and took the survivors back to England with him. Drake and Raleigh were old friends. Raleigh was interested in agriculture and had then recently acquired a large estate near Cork, in Ireland. It is a natural supposition that Drake had obtained the potatoes from the

[17] A footnote in this little volume calls attention to the fact that Appel de Kapoesang was the first successful cultivator of the potato in Austria. See Johnson, George W., The potato: Its culture, uses, and history, p. 3. London, 1847.

Spaniards in the West Indies, where they grow fairly well in the mountainous sections [18] and gave them to Raleigh and that Raleigh gave them a trial on his Ireland farms as has been so commonly stated.

Notwithstanding the author's theory that Drake had obtained Irish potatoes from the West Indies, he once more confuses them with the Virginian openawk, included by Heriot in his list of foods of Roanoke Island, declaring that if any man is to be given credit for the introduction of Irish potatoes into European agriculture, the honor should go to Heriot rather than to Drake or Raleigh.[19]

THE POTATO OF REALITY

Writers on the origin of cultivated plants who for their information depend upon the accounts of early travelers, missionaries, and colonists are apt to be mistaken in their identification of species. Many of these accounts, written by persons ignorant of botanical relationships or the essential features by which genera and species may be distinguished, give little indication of the true nature of the plants they describe. Thus, as I have already shown, Heriot's account of the openauk, of which he described only the tubers and the habitat, caused it to be confused for more than three centuries with the potato. From the account of the botanist Kalm, who speaks of its bean-like pods, we know at once that the plant belongs to the Leguminosæ. Even botanists have disputed for years the origin of several well-known plants, including beans, peanuts, and squashes, owing to the resemblance of certain species of the Old World to those of America.

TESTIMONY FROM PREHISTORIC TOMBS

Fortunately, for a knowledge of the economic plants of western South America we do not have to turn to literature. Along the arid desert which forms the Pacific coast of Peru and northern Chile there is a succession of cemeteries in which mummies are found accompanied not only by desiccated plants and plant products, but also, in many cases, by funeral vases of terra cotta, some of which represent food staples and fruits of the ancient inhabitants. Owing to the absence of rain in this region the soil remains impregnated with sodium nitrate which has acted as a preservative of organic material, so that even in ancient refuse heaps on the surface as well as in the tombs, both vegetable and animal substances have been preserved in a remarkably perfect condition.

[18] It has been established without any doubt that *Solanum tuberosum* did not grow in the West Indies until the early part of the eighteenth century, when it was cultivated in the mountains of Jamaica from tubers imported from Ireland and Lancashire under the name of Irish potatoes.

[19] Carrier, Lyman. The Beginnings of Agriculture in America, pp. 81 and 84. 1923.

Among the plant products and representations of fruits and vegetables dug up by the author in Peru, the most common were maize and maize gods, beans (*Phaseolus vulgaris*) both round and kidney-shaped, lima beans (*Phaseolus lunatus*) shaped somewhat like the Old World broad bean or faba, peanuts (*Arachis hypogœa*), several varieties of squashes (*Cucurbita pepo*), round and crook-necked, smooth and warty, hard-shelled gourds (*Cucurbita lagenaria*) used as containers, and—most interesting of all—*Solanum tuberosum*, the papas of the Quichuas, either dried or represented in terra cotta, sometimes as facsimiles of the original tubers, but more often conventionalized in black or red pottery.[20] Dried potatoes were found by the author in graves at Arica on the coast of northern Chile in 1887, together with arrow points and llama-drivers' slings from the elevated plateau about Lake Titicaca. Terra cotta huacas, or funeral vases, representing potatoes were most abundant in graves near Chimbote and Chepen, northern Peru. In the accompanying illustrations, Plate 6, Figure 2 shows a collection of food products from pre-Columbian graves in the New York Museum of Natural History; Plate 7, Figure 1 is a funeral vase from Chimbote representing two potatoes in natural colors; and Plate 7, Figures 2 and 3, show vases of black ware from the same locality in the form of conventionalized potatoes. *Solanum tuberosum* can not be cultivated successfully at low elevations in the tropics, so that the potatoes, which were evidently an important food staple of the early inhabitants of the Chimbote region, must have been brought down from the nearby mountains. These dried potatoes and representations of potatoes were certainly interred with the dead in pre-Columbian times. They are the most ancient illustrations of potato culture in existence.

TRUE HISTORY OF THE POTATO

The first published account of *Solanum tuberosum* is that of Pedro de Cieza de Leon, who, in 1538, encountered it in the upper Cauca valley between Popayan and Pasto, in what is now Colombia, and afterward at Quito, now the capital city of Ecuador. At that time he passed through villages so high above sea level that maize would not grow in their vicinity, where the principal food crops mentioned by him were papas and quinoa (the minute seeds of *Chenopodium quinoa*), both of which are still the most important foods of the mountains and elevated plateau of western South America.

In his Chronica del Peru, a journal written from night to night while his comrades were sleeping, Cieza de Leon describes the papas

[20] See Safford, W. E. Food plants and textiles of ancient America, in Proceedings of the 19th International Congress of Americanists, pp. 12–30, 1917.

as "a kind of ground nut, which when boiled becomes as soft as a cooked chestnut, but which has no thicker skin than a truffle." Afterwards, in writing of the elevated Collao region, he speaks of it in greater detail. The inhabitants of that part of the world live in villages surrounded by cultivated fields: "Their principal sustenance is papas, which, as I have already stated in this history, are like turmas de tierra. These they dry in the sun and keep from one harvest to the other. And they call this papa, after it is dried, 'chuño,' and among them it is esteemed and held precious; for they have no ditches like many others in this kingdom to irrigate their fields, and if there is a dearth of natural water to make their crops grow they suffer from lack of food and work unless they are provided with this sustenance of dried papas. And many Spaniards have become rich and returned to Spain prosperous only from carrying chuño to sell to the mines of Potosi."[21]

Cieza also describes the great sandy desert along the Pacific coast traversed at intervals by ribbons of verdure, where streams from the Andes make their way seaward, not always, however, reaching their destination. In this region he was much impressed by the numerous cemeteries to which I have already referred, and by the vestiges of cultivated fields which, even at that early time, had long been abandoned, and whose ancient tillers were sleeping in the adjacent tombs.

Cieza's Chronica, first published in folio at Seville in 1553, was followed the next year by a small size edition printed at Antwerp by the famous publisher Jan Steeltz and by a third, in Italian, printed at Rome in 1555. It was eagerly read as the first authentic account of South America.

Padre José de Acosta, a Jesuit missionary, who was in South America from 1571–1576, was the next author to treat of the Peruvian papas which he observed in their original habitat. After writing of yuca or manioc in his account of the edible roots of the New World, he says: "In the elevated region of the Sierra of Peru and the provinces which they call the Collao, composing the greater part of that kingdom, where the climate is so cold and dry that it will not permit the cultivation of wheat or maize, the Indians use another kind of roots which they call 'pappas,' a kind of turmas de tierra that send up scant foliage (echan arriba una poquilla hoja). These pappas they collect and leave in the sun to dry well, and breaking them they make what they call 'chunyo' which will keep for food in that form many days and serves them for bread; and of this chunyo there is great commerce in that kingdom with the

[21] Parte primera de La Chronica del Peru—Hecha por Pedro de Cieza de Leon, Antwerp edition, p. 243. 1554.

mines of Potosi. Pappas are also eaten fresh either boiled or roasted; and from one of the mildest varieties which also grows in warm situations they make a certain ragout or cazuela which they call 'locro.' Indeed, these roots are the only wealth of that land, and when the season is favorable for the crop they (the Indians) are glad; for many years the roots are spoiled and frozen in the ground, so great is the cold and bad climate of that region."

In preparing chuño, potatoes were subjected to freezing as well as drying. The process is described in detail by Padre Bernabe Cobo, who writes as follows: "The tubers are gathered at the beginning of the cold season, in May or June, spread out on the ground, and exposed for a period of 12 or 15 days to the sun during the day and the frost at night. At the end of this time they are somewhat shriveled, but still watery. In order to get rid of the water, they are then trampled upon and then left for 15 or 20 days longer to the action of the sun and frost, at length becoming as dry and light as a cork, very dense and hard, and so reduced in bulk that from four or five fanegas of fresh tubers there results only one fanega of chunyo." Cobo adds that chunyo thus prepared will remain unspoiled for many years and that the Indians of the Collao provinces eat no other kind of bread. "A choicer and more highly prized quality is prepared by soaking the tubers in water for about two months after their preliminary drying. They are then taken out and dried in the sun once more. This quality of chunyo, which is chalky white within, is called 'moray.' From it a kind of flour, finer than wheat flour, is prepared by the Spanish women, who use it for starch, biscuit, and sweetmeats of all kinds, like those confections usually made with sugar and almonds." [22]

In the economic herbarium of the United States Department of Agriculture are specimens of chuño from ancient coast graves, and in various museums of ethnology in America and the Old World there are huacas, or funeral vases, representing tubers of *Solanum tuberosum* similar to those I have already described. The accompanying illustration, Plate 6, Figure 1, for which I am indebted to the Hon. Hiram Brigham, shows the elevated Peruvian Collao with piles of potatoes and Quichua Indians preparing chuño exactly as they did at the time of the visits of Cieza de Leon, Acosta, and Padre Cobo. Plate 8 is an original photograph of moray, or white chuño, in the United States National Museum, collected by Mr. O. F. Cook, of the Bureau of Plant Industry, between Sicuani and Santa Rosa, on the road from Cusco to Lake Titicaca.

[22] Cobo, Bernabe, Historia del Nuevo Mundo (1653) 1: 361. 1890.

POTATOES CULTIVATED BY THE INDIANS OF SOUTHERN CHILE

In November, 1578, Sir Francis Drake encountered tubers of *Solanum tuberosum* in use as a food staple by the Indians of southern Chile, where they are still extensively cultivated. Their occurrence at sea level in this part of South America is not singular, for, as all students of plant distribution well know, many species characteristic of the Andean vegetation thrive at altitudes lower and lower as they extend southward, reaching sea level in the region of the Chonos Archipelago and the Straits of Magellan. Within less than a decade after Drake's visit, these tubers had become a regular food on Spanish ships. On March 16, 1587, Thomas Cavendish, stopping at St. Mary Island, near Concepcion, southern Chile, found "Cades of strawe filled with potato rootes, which were very good to eat, ready made up in the storehouses for the Spaniards, against they should come for their tribute." At this very early date, less than a century after the discovery of America, Cavendish found wheat and barley in cultivation in southern Chile, and "Hogges and Hennes" had also been introduced. "The Indians of this Island," said Master Francis Pretty, who wrote the narrative of the voyage, "are held in such slavery by them (the Spaniards) that they dare not eate a Henne or an Hogge themselves. But the Spaniards have made them all in that Iland Christians. Thus wee fitted ourselves here with corn as much as wee would have and as many Hogges as wee had salt to powder them withal, and great store of Hennes, with a number of Bagges of Potato rootes, and about 500 dried Doggefishes, and Guinie Wheat which is called maiz (by the Spaniards)."

Sailing northward, looting the coast towns as he went, Cavendish captured the *Santa Anna*, the Spanish "admirall," or flagship, off the coast of Mexico, taking from her three young Filipinos, "borne in the Isles of Manilla"; also a Spaniard, whom he caused to be hung, after having been piloted by him from the Mexican coast to Guam and the Philippines. The "potato rootes" he encountered in the latter islands were not *Solanum tuberosum*, but sweet potatoes, *Ipomoea batatas*, easily recognizable by their Aztec name, "Camote," which had accompanied them from Mexico, and which they still bear in those islands.[23]

Cavendish, like Drake, returned to England around the Cape of Good Hope. Whether he brought back potatoes with him is not known, but it is quite certain that it was not he who introduced them

[23] Camotes, or sweet potatoes, are the principal food crop of the hill-tribes of northern Luzon, where they are extensively cultivated on terraced hillsides. It is declared by the natives that their fathers always possessed them.

into Europe, for he arrived at Plymouth the 9th of September, 1588, and more than eight months before this, on January 26, 1588, Charles de L'Ecluse, or Carolus Clusius, at that time in charge of the botanical gardens of Rudolph II, at Vienna, received from Philippe de Sivry, Prefect of Mons in the Belgian province of Hainault, two potato tubers which he planted in his garden. These had been sent to de Sivry by an attaché of the papal legation, who had them from Italy, where they had been in cultivation since about 1585. The year following de Sivry sent to Clusius an excellent colored drawing, now in the Plantin-Moretus Museum at Antwerp, which bears the following inscription in the handwriting of Clusius:

Taratoufli a Philippo de Sivry acceptum Viennae 26 januarii 1588.—Papas Peruanum Petri Ciecae.

This drawing is reproduced in the accompanying illustration (pl. 9). Its accuracy is shown by comparing it with plate 10, an original photograph of a specimen in the economic herbarium of the United States Department of Agriculture, propagated from a tuber collected at Oruro, Bolivia, by Mr. W. F. Wight (No. 415).

At the time the drawing was made an interest in the potato had been awakened by the appearance of Acosta's account of the New World, published first at Salamanca in Latin in 1588–89, and the following year at Seville in Spanish, under the title Historia Natural y Moral de las Indias. Acosta dedicated his work to "La Serenissima Infanta, Doña Isabel Clara Eugenia de Austria."

It seems strange that a nourishing and easily cultivated food staple like the potato, to whose excellence both Cieza and Acosta had called attention, should have to wait so long for recognition. Other cultivated plants of the New World, like maize, beans, and tobacco, became widely spread in a remarkably short time after the discovery of America.

The exact date of its introduction into Europe is not known. It was, however, undoubtedly carried thither from Peru as a curious food of the New World, possibly by the same Spaniards who, according to Cieza, returned to Spain after having grown rich by carrying chuño to the mines of Potosi.

Owing to Clusius' delay in publishing his data, he was anticipated by Gerard, who was indebted to him for information regarding the potato, as he himself states in his Herbal. It was not Gerard who gave to the potato its accepted botanical name, but Kaspar Bauhin, who, in 1596, described it accurately under the very appropriate name, *Solanum tuberosum*, which Linnæus adopted.[24]

Like Clusius, Bauhin identified it with the papas of Spanish America. His illustration was made from a specimen grown in the

[24] See Kaspar Bauhin, Phytopinax, seu enumeratio plantarum. 302. Basil. 1596.

garden of Doctor Scholtz at Breslau, in Silesia, to which I shall refer later. Clusius' description, although antedating the publications of Gerard and Bauhin, did not appear until 1600.[25]

INTRODUCTION OF THE POTATO INTO CULTURE

For more than a century *Solanum tuberosum* continued to be grown as a curious exotic plant in gardens both in England and on the Continent before it began to attain a reputation as a food staple. Its value was first recognized in Ireland, where conditions of soil and climate were peculiarly favorable for its propagation. An illustration after a painting by Francis Walker of two young women digging potatoes in County Donegal was published in Frank Matthews's Ireland (edition of 1912). The surrounding landscape in this lovely picture (pl. 11) suggests the coast islands of southern Chile where both Drake and Cavendish found the potato extensively cultivated in the sixteenth century, as related in the first part of this paper. Not only do the Irish and Chilean habitats resemble each other but the climates of the two regions are also similar; that of southern Chile, influenced by the Humboldt Current which sweeps northward along the coast, and that of Ireland by the beneficent Gulf Stream, which tempers the climate of the islands and shores of the western coast.

It was the Irish peasants who first took up the cultivation of the potato, and it soon became their only food crop, serving for breakfast, dinner, and supper. Their affection for it is shown by many pet epithets, including the "flowery potato," and the "laughing potato." The simplest form in which it was eaten by them was baked or boiled and dipped in a saucer of salted milk. Between meals the children were allowed to roast potatoes on their own account in the turf or wood ashes. It was a common sight in passing a cottage to see a group of little ones run to the door, each with a roasted potato in his hand. While they lasted there was no dearth of wholesome food. When the supply was exhausted it was necessary to buy oatmeal, which was made into a sort of pudding or thick porridge called "stir about." Potatoes served as food also for the family pig, the dog, and a few fowls. The poor had little else except perhaps buttermilk at breakfast and supper. If the family possessed a cow, there was also butter, which was used for frying delicious potato cakes. It was not long before the Irish learned to use potatoes as a source of whisky, in the preparation of which they reduced the potatoes to a paste or pulp, added yeast and, after it had undergone a process of fermentation, distilled it into a clear

[25] Clusius, Rariorum plantarum historia, lib. 4, p. 78, 1601.

alcoholic liquor which was called "poteen" from the small pots used in the process.

From its skin they prepared a soup, and they used the water in which potatoes are boiled as a curative wash for sprains and broken limbs. Perhaps the most delicious potato preparation of all was that called "pardy" or "cal-carron," made from new potatoes. For the Irish the potato acquired an almost sacred significance, as the daily bread which they received in answer to their prayers. In certain localities it was customary at the time of planting for the parish priest to march solemnly to the field and bless it, praying for a bountiful harvest. The potato, however, was not an unmixed blessing to Ireland. Though it yielded an abundant return for little labor, yet the occasional failure of the crop caused unspeakable misery to the people, for in their economy it had taken the place of oatmeal and all other foods.[28]

By whom and when the potato was introduced into Ireland is not definitely known, but we know that it was cultivated there as a field crop before 1663, a year of dearth in Great Britain and Ireland. In March of that year the attention of the Royal Society was called to it as a crop of national importance by Mr. Buckland, a Somersetshire gentleman, and such members of the society as had lands adapted to its culture were entreated to plant the new vegetable. The recommendation was reported favorably by a committee to whom it was referred, and Mr. Evelyn, the celebrated practical gardener of that period, was requested to enforce the society's opinion in the Sylva, at that time published under the society's auspices. It is evident that it found no favor with him, for in 1664, in his Kalendarium Hortensi, the first gardener's calendar published in Britain, he gives the following advice: "Plant potatoes in February in your worst ground." In 1664, before the Sylva appeared, there was published the first pamphlet advocating the cultivation of the potato in England. It bears the following prolix title: "England's happiness increased, or a sure and easy remedy against all succeeding dear years by a plantation of the roots called potatoes, whereof (with the addition of wheat flour) excellent, good, and wholesome bread may be made every year, eight or nine months together, for half the charges as formerly. Also, by the planting of these roots 10,000 men in England and Wales who know not how to live or what to do to get a maintenance for their families, may, off 1 acre of ground, make £30 per annum. Invented and published for the good of the poorer sorts by John Forster, Gent., of Harslop, in Buckinghamshire." The author identi-

[28] For most of this information I am indebted to Rev. John J. Queally, rector of the Church of the Transfiguration, Washington, D. C.

fies the potatoes recommended as Irish potatoes, declaring that "these roots, although they came at first from the Indies, yet prosper well in Ireland, where there are whole fields of them, from whence they have been brought into Wales and the north parts of England, where they likewise prosper and increase exceedingly."

After recommending methods for their cultivation, Forster gives directions for making potato bread, potato biscuits, potato pudding, potato custards, and potato cheese cakes. He declares that in good ground there will be a yield of 3 or 4 heaped bushels per rod, for which no one will grudge a shilling per bushel. Treating the propagation of potatoes as a political measure, he earnestly recommends the King, Charles II, to order potatoes to be imported from Ireland; that every man in every parish shall grow an acre or two; and suggests that out of every £30 worth grown in a parish, £5 shall be paid as tribute to the King.

Notwithstanding the publication of this earnest appeal and its indorsement by the Royal Society, the introduction of the potato as a field crop was extremely slow. Before 1699 potatoes had been introduced into Lancashire, where they became very common. It was from Lancashire and Ireland that they were carried to the British West Indies in the early part of the eighteenth century and were propagated in the mountains of Jamaica under the name Irish potatoes, and from Lancashire also they began to spread over England. They were mentioned slightingly in publications early in the eighteenth century. Loudon and Wise, in the seventh edition of their "Compleat Gardener" published in 1719 did not even mention the potato, and as late as 1770 it was not known generally in the southwestern counties.

In Scotland potatoes were first cultivated as a field crop in 1739, but were not known in the Highlands until 1743. Although their culture by the cottagers was successful they did not meet with favor among the higher classes, while zealous Presbyterians looked at them askance, declaring that potatoes are not mentioned in the Bible. It was not until they were urged by hunger that the Scotch seriously took up the cultivation of the potato and became convinced of its excellent qualities.[27]

THE POTATO IN PRUSSIA AND FRANCE

Everyone knows the story of the introduction of potato culture into Prussia, which Frederick the Great and his eccentric father were so active in accomplishing. It has recently been told anew in a paper read before the second Potato Congress held at Breslau in

[27] For much of the foregoing information relating to the introduction of the potato into Ireland and Great Britain I am indebted to a monograph entitled "The Potato: Its Culture, Uses, and History," by George W. Johnson. London, 1847.

October, 1923, by E. Duczek.[28] The important part which the potato has assumed in the economy of the German people is indicated in this article by the preliminary prayer: "Unser taeglich Brot, gib uns Heute!"—and the reverence felt for the beneficent autocrat is expressed at the end in a beautiful tribute to "Fridericus Immortalis." In preparing his paper, Duczek had access to documents in the archives at Breslau, many of them faded and yellow with age, in which potatoes figure under the names "Kartoffeln," "Tartoffeln," and the quaint hybrid combination "Erdtoffeln." Like all of his predecessors in potato literature, he begins with the Drake, Hawkins and Heriot myths and the story of the disgruntled gardener—whether Raleigh's or Drake's, he does not specify.

He then goes on to tell the story of the introduction of the potato into his native province, pointing out that it was first cultivated at Breslau in the garden of Dr. Laurentius Scholtz. This celebrated garden, already referred to as the source of the potatoes used by Bauhin for his illustrations, was reproduced as faithfully as possible in honor of the Potato Culture Exposition of 1913 at Breslau. The first active measures taken for the introduction of the potato into Prussia were those of the great Elector, Frederick William, who in 1651 caused potatoes to be planted in the Berlin Lustgarten. On Plate 12 the Grosser Kurfuerst is shown with his consort inspecting the potatoes planted by his orders. His grandson, King Frederick William I, in his effort to foster potato culture, resorted to drastic steps, threatening to cut off the noses and ears of all who refused to plant them. He also decreed that they should be fed to the poor inmates of the Berlin Charitee and presented to the hospital a piece of land to be used solely for their cultivation; but the real credit for promoting potato culture in Prussia, especially in Silesia and Pomerania, must be awarded to his illustrious son, Frederick the Great. In the year 1744, Frederick II caused seed potatoes to be gratuitously distributed and compelled the peasants to cultivate them. Not only were edicts and ordinances issued, but the local authorities were warned that their duties did not cease with the promulgation of the decrees. They were held responsible for their practical enforcement through the aid of the land dragoons, and were expected to make official reports from time to time setting forth the condition of potato plantations in their districts and the zeal shown by the peasants in cultivation of the crop.

In the Breslau archives Herr Duczek found two original royal circulars, the first dated March 24, 1756, the second April 5, 1757, both of them showing remarkable familiarity on the part of Fred-

[28] See Zeitschrift der Landwirthschaftskammer Schlesien. Kartoffelnummer. 27 Jahrgang, p. 1152. Oct. 27, 1923. For this publication I am indebted to Dr. Otto Appel, Direktor der Biologischen Reichsanstalt für Land u. Forst-Wirthschaft, Berlin-Dahlem; also for the number of Mar. 15, 28 Jahrgang, 1924.

erick the Great with the best methods of potato culture. In the second circular, which was published in full in the later number of the Breslau Zeitschrift, the King advises that potatoes be planted in the dark of the moon. He also indicates the proper time of plowing, manuring, and planting the fields, cautioning the farmers that if they plant small potatoes they will raise small potatoes, while the best results will follow from the selection of large tubers, which should be so cut as to leave an eye in each piece. He also instructs them how to keep potatoes in straw-lined pits through the winter, and that although potato patches do not need the same protection from cattle and sheep as grain fields, yet care should be taken not to herd swine in their neighborhood. After digging them, at Michaelmas, the hogs need no longer be kept away, but may be allowed to rush in and eat their fill of the tubers left in the ground. The circular ends with various recipes for the preparation of potatoes as food for both man and beast.

These circulars, enforced by local officials, had their effect, but it was famine, caused by the Silesian wars, especially the Seven Years War, which established potato culture in Prussia on a firm basis.

The introduction of potatoes into France was largely due to the celebrated Antoine Auguste Parmentier, who, while a prisoner in Germany, during the Seven Years War, was fed upon potatoes and learned to like them. He was then serving as pharmacist in the Hanover army, and during his hours of captivity he conceived the idea of introducing potato culture on a grand scale into his own country. Potatoes had hitherto been in bad repute in France, owing to the attacks made upon them by physicians, who declared that they were poisonous and were the cause of many maladies. A set of colored woodcuts published in a series of educational pictures, called the Serie Encyclopédique" Gluq, des Leçons des Choses Illustrées,[29] tells the story of Parmentier's success. After his return to France, while serving as pharmacist at the Invalides, he entertained Benjamin Franklin, Lavoisier, and other distinguished guests with a great dinner at which the bill of fare consisted entirely of potatoes served in various ways. Yet there were still learned agronomists who declared that although the potato might be a good vegetable it would be dangerous to introduce it, for it would ruin the soil wherever it was planted. Then Parmentier, to prove the falsity of these assertions, obtained from Louis XVI permission to plant potatoes in a piece of land called "Les Sablons," notorious for its sterility. When in a short time the potatoes sprouted and this field, which hitherto had been known only as a sandy waste, assumed the appearance of a blooming garden, people began to believe that Parmentier

[29] *See* Journ. Heredity, 16: 222. 1925.

was right. In order to forward his ends, he caused his potato plantation to be guarded by soldiers in full uniform throughout the day, under the pretext of preventing depredations; but at night the guard was withdrawn, whereupon a number of people, allured by the attraction of forbidden fruit, came secretly to steal potatoes, to plant them in their own gardens or to eat them. This was the very object which the good Parmentier had in view. When the plantation at Les Sablons was in full bloom Parmentier made a great bouquet of potato blossoms which he carried to Versailles and presented to Louis XVI. The King placed one of the flowers in his buttonhole, and in the evening Marie Antoinette appeared with a cluster in her hair. This was sufficient. All the court followed the example of their sovereigns. In graciously accepting Parmentier's offering, the King said: "France will thank you some day for having found bread for the poor."

No statue has been erected in Parmentier's honor, but on his grave in the cemetery of Père Lachaise potatoes bloom each year, showing that he has not been forgotten by the people of France.

THE POTATO IN NORTH AMERICA

Instead of having been taken from North America to Great Britain and Ireland, as set forth in the myths regarding the "Virginia potato," *Solanum tuberosum* was first brought from Ireland to North America, where it is known as the "Irish potato." This happened in 1719, when a colony of Scotch-Irish immigrants established a settlement at Londonderry, Rockingham County, N. H., bringing with them potatoes and flax. Hazlett, in his history of Rockingham County, gives the following account of this settlement:

> The first crops raised by the emigrants were potatoes and flax. They had brought their seed and spinning wheels from Ireland and were the first to cultivate the potato and manufacture linen in New England. They appear to have cultivated land in common the summer after their arrival, as there is a tract known by the name of the "Common Field," containing about 2½ acres and situated a few miles west of the dwelling house of Mr. Jonathan Cate, in Derry. It was undoubtedly a clearing, and may have been an abandoned planting ground of the Indians, who were gradually retiring to deeper shades of the wilderness in the wilds of Canada.[30]

A more detailed description, with perhaps a flavor of romance, is given by Parker in his "History of Londonderry." Describing the arrival of the settlers of this town, he says:

> They introduced the culture of the potato, which they brought with them from Ireland. Until their arrival, this valuable vegetable, now regarded as one of the necessities of life, if not wholly unknown, was not cultivated in New England. To them belongs the credit of its introduction to general use. Although highly prized by this company of settlers, it was for a long time but

[30] Hazlett, Charles A. History of Rockingham County, N. H. Page 506. 1915.

little regarded by their English neighbors, a barrel or two being considered a supply for a family. But its value as food for man and for beast became at length more generally known, and who can now estimate the full advantage of its cultivation to this country? The following well-authenticated fact will show how little known to the community at large the potato must have been. A few of the settlers had passed the winter previous to their establishment here in Andover, Mass. On taking their departure from one of the families, with whom they had resided, they left a few potatoes for seed. The potatoes were accordingly planted, came up and flourished well; blossomed and produced balls, which the family supposed were the fruit to be eaten. They cooked the balls in various ways, but could not make them palatable, and pronounced them unfit for food. The next spring, while ploughing their garden, the plough passed through where the potatoes had grown, and turned out some of great size, by which means they discovered their mistake.

It is not the province of this paper to follow the development of potato culture in the United States. For this the reader is referred to the admirable monograph on the potato by William Stuart, of the United States Department of Agriculture, who treats of its culture, uses, history, and classification.

SEARCH FOR THE WILD ANCESTOR

Has the potato ever been found growing wild? Several explorers have encountered what was believed to be the wild form. Charles Darwin, in January, 1835, found wild potatoes growing in the Chonos Archipelago, southern Chile, not far from where cultivated potatoes were procured by Sir Francis Drake and Thomas Cavendish. These, however, as well as tuber-bearing Solanums collected in Peru, Mexico, and the southwestern United States have proved to be quite distinct from *Solanum tuberosum*. Specialists who have devoted themselves to the study of tuber-bearing Solanums unite in their declaration that the true *Solanum tuberosum* has never been found growing wild. Dr. George Bitter, of Bremen, emphasizes the fact that the problem of the origin of our cultivated potato is still unsolved and that we know nothing of its original form before it was cultivated by the Arauco Indians of Chile and the Incas of Peru. Both he and Rydberg show that the so-called *Solanum tuberosum boreale* of our Southwest is not a variety of the true potato; and Mr. W. F. Wight, after a long journey of exploration in South America and careful research among specimens in herbariums of Europe and America declares that "every reported occurrence of wild *Solanum tuberosum* that I have been able to trace to a specimen, either living or preserved in the herbarium, has proved to be a different species. In fact, so far as the herbarium material is concerned, I have not found in any of the principal European collections a single specimen of *Solanum tuberosum* collected in an undoubtedly wild state. After a century and a half of intermittent collecting, there is no botanical evidence that the species is now growing in its original indigenous

condition anywhere. * * * So far as the number and relationship of the species referred to the section Tuberarium are concerned, the evidence is favorable to the central Andean region.[31]

SUMMARY

From the evidence presented in this paper the following summary may be made:

I. The statement that the potato was found growing in North America by the English colonists and carried thence to England, for which Gerard is responsible, is not true; the openawk of the Algonquin Indians with which it was confused by early writers is a tuber-bearing climber of the bean family, the *Glycine apios* of Linnæus.

II. The story of its introduction into Ireland by Sir Walter Raleigh is a myth invented in 1693, more than a hundred years after the return of his ill-fated colony from Roanoke Island. The Drake myth which was substituted for it is equally without foundation.

III. The cultivation of *Solanum tuberosum* in pre-Columbian times extended from southern Chile along the Andes and the highlands of Peru and Bolivia to the mountains of Ecuador and Colombia, but did not reach the shore of the Caribbean Sea. The "potatoes" encountered on the shore and islands of that sea by early navigators were sweet potatoes.

IV. It was carried to Europe from South America by the Spaniards soon after 1580, thence to Italy, and in 1588 reached Charles l'Ecluse, keeper of the botanical garden at Vienna. It was cultivated as a field crop in Ireland before 1663. It did not reach the United States until 1719, when it was brought from Ireland by immigrants who settled at Londonderry, N. H. The Irish potato reached the West Indies after 1700, and was first propagated from seed brought from the British Isles.

V. Dried specimens and representations of potatoes in terra cotta found in prehistoric tombs show that excellent varieties had been developed before the discovery of America.

VI. Numerous species of tuber-bearing Solanums have been collected in various parts of America both north and south of the equator, but *Solanum tuberosum* itself has never been found in its wild state. Evidence as to the place of its origin points to the central Andean region where conditions of soil and climate are such that a number of plants of other families have developed tubers of a similar nature.

[31] Wight, W. F. Origin, introduction, and primitive culture of the potato, in Proceedings of the Third Annual Meeting of the Potato Association of America, p. 37. 1916.

JOHN GERARD

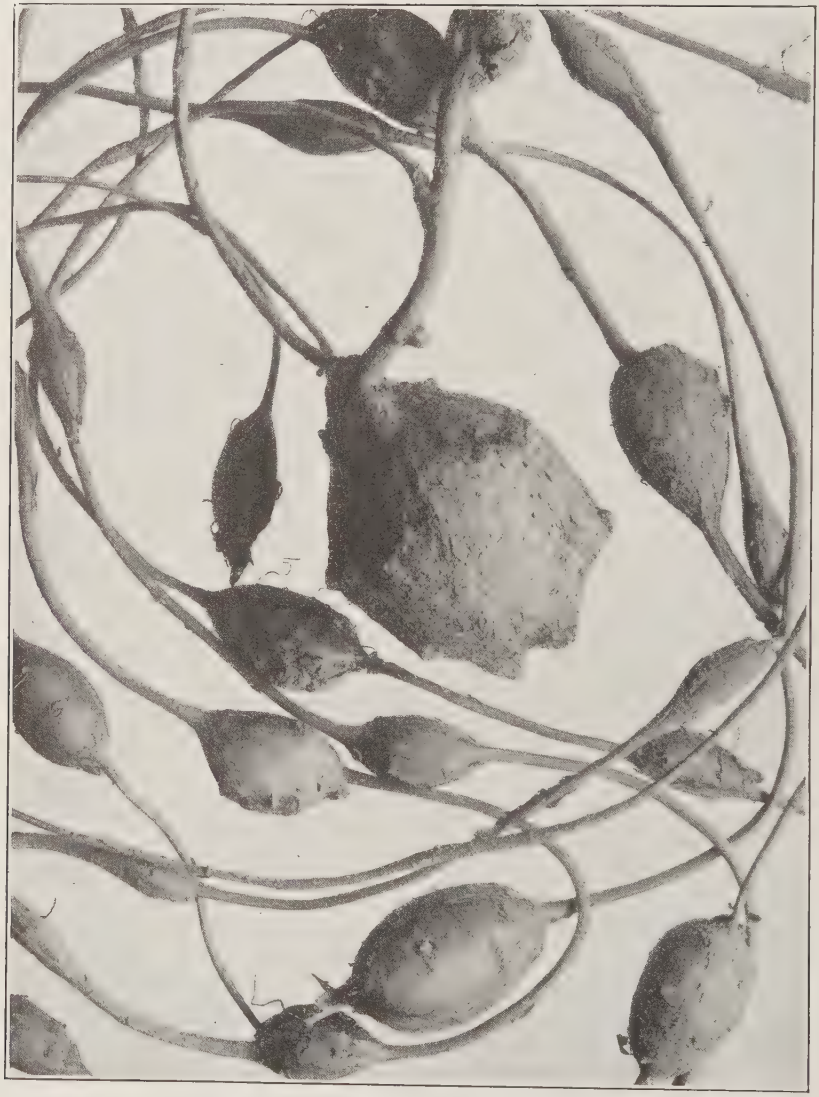
He is holding in his hand a flowering branch of *Solanum tuberosum*, which he called *Battata sive Virginianorum & Pappus*, pretending to have received from Virginia the tuber from which it was propagated. He must be held responsible for the transfer of the name Potato from *Ipomoea batatas* to *Solanum tuberosum* and for the confusion of the latter with the Openauk of Virginia. Portrait reproduced from his Herbal. 1597

THE ORIGINAL POTATO, NOW CALLED SWEET POTATO

Opomoea batatas. Confused by early writers with *Solanum tuberosum*. Observed first by Columbus, November 4, 1492, and described in his journal as "Niames (yams) resembling carrots, with a savor of chestnuts." Identified by Las Casas, his contemporary, as "Ajes" or "Batatas." Collected at Santa Fe, on the north coast of South America, in 1565 by Sir John Hawkins, who described it as "the most delicate roots that may be eaten." Photograph of specimen growing in the garden of Harry A. Allard, Bureau of Plant Industry

THE VIRGINIA POTATO OR OPENAUK

Glycine apios, the Openauk or Penak of the Algonquin Indians. A plant of the Bean family, with edible tubers and pealike seeds, endemic in eastern North America from Florida to the St. Lawrence River. Encountered by Sir Walter Raleigh's second colony on Roanoke Island in 1586. Photographed from a specimen collected by O. M. Freeman in marshy thicket in Virginia, across the Potomac River from Washington



OPENAUK ROOTS OR INDIAN POTATOES

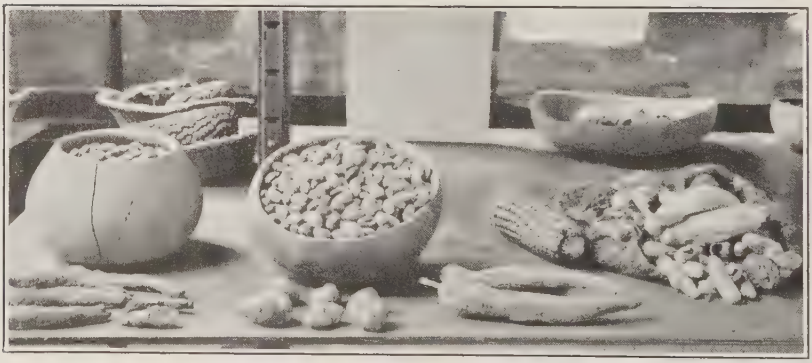
Tubers called Openauk by the Virginia Algonquins and Penak by those of Canada. "A kind of rootes of round form, some of the bignes of walnuts, growing many together one by another, or as thogh fastened with a string."—Thomas Heriot. 1588. Photographed from a specimen collected by J. B. Norton, near Washington, D. C.

A GERMAN MONUMENT TO DRAKE

Sir Francis Drake holding a potato plant with its tubers attached. This monument stands in Offenburg, Baden, in commemoration of his alleged introduction of the Potato into Europe. The inscription on the statue reads: "Sir Francis Drake, introducer of the Potato into Europe, in the year of our Lord 1580." Note the potato plant in Drake's hand and the decorative frieze of potatoes around the base of the statue. From a photograph received through the kindness of Dr. Otto Appel of Berlin-Dahlem

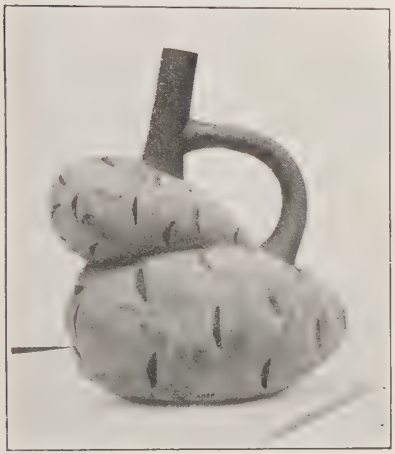
1. DRYING POTATOES FOR CHUÑO

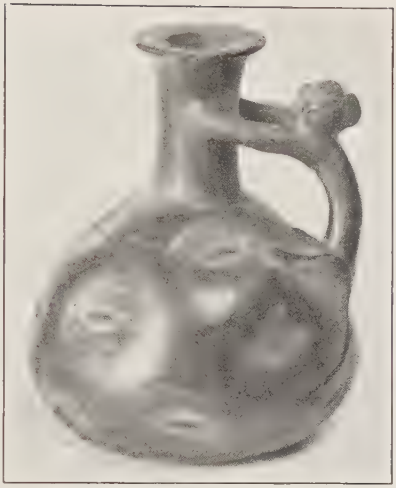
View of the elevated Peruvian Collao, showing Quichua Indians preparing Chuño. Photograph received from the Hon. Hiram Bingham. See National Geographic Magazine, April, 1913, page 568



2. ANCIENT FOODS FOUND WITH PERUVIAN MUMMIES

Food staples found in Pre-Columbian graves of the coast of Peru, including several varieties of beans (*Phaseolus vulgaris*), lima beans (*Phaseolus lunatus*), manioc (*Jatropha manihot*), maize (*Zea mays*), peanuts (*Arachis hypogaea*), sweet potatoes (*Ipomoea batatas*), and *chunyos*, or dried potatoes. The latter in the central foreground. Original photograph of specimens in the American Museum of Natural History, New York





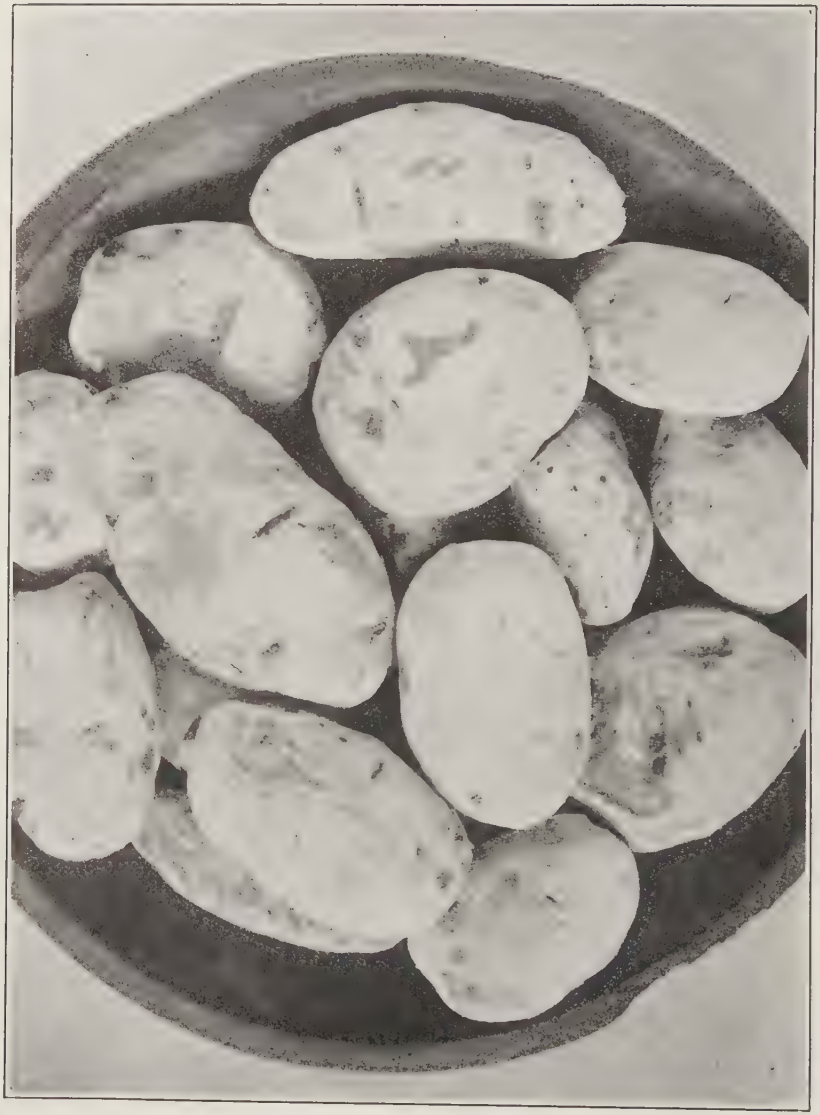
POTATO VASES

1. A funeral vase in the form of two potatoes in natural colors from a grave at Chimbote, on the coast of Peru, collected by W. E. Safford, 1892. Field Museum, Chicago, No. 1188

2. Black ware vase from a Chimbote grave, in the form of a conventionalized potato. Collection of Spencer F. Baird, U. S. National Museum. Original photograph

CONVENTIONALIZED POTATOES

3. A whistling *huaca* of black ware, in the form of conventionalized potatoes, from a Chimbote grave. Collection of Spencer F. Baird in the U. S. National Museum. Original photograph



MORAY OR WHITE CHUÑO

Potatoes frozen, dried, trampled, soaked in water, and dried again. Specimens in U. S. National Museum collected by Mr. O. F. Cook, U. S. Department of Agriculture. Original photograph

OLDEST DRAWING OF THE POTATO

Drawing received by Charles de L'Ecluse from Philippe de Sivry, January 26, 1588. The earliest European illustration of the potato. Original in Plantin-Moretur Museum at Antwerp

A MODERN POTATO

Herbarium specimen of *Solanum tuberosum* and tuber from which it was grown. Collected by Mr. W. F. Wight at Oruro, Bolivia. Original photograph

POTATOES A NECESSITY

Mother and daughter digging potatoes on the coast of Ireland. From a painting by Francis Walker published in Frank Matthew's Ireland (edition of 1912)

POTATOES A CURIOSITY

The Great Elector, Frederick William, with his consort, inspecting the potatoes planted by his order in the Berlin Lustgarten. Not until the reign of his great-grandson, Frederick the Great, did the potato become a popular food staple in Prussia. Photograph of etching by Ebner, received through the courtesy of Doctor Appel

THE RELATION OF GEOGRAPHY TO TIMBER SUPPLY[1]

By W. B. Greeley

Chief, United States Forest Service

[With 3 plates]

Even since Hiram, King of Tyre, shipped rafts of fir and cedar down the Mediterranean coast to trade with the Jews of Solomon's day, timber has been an important factor in the commerce of the nations. Among the first exports from the American colonies to the mother country were clapboards split from the oak of Virginia, ship masts cut from the pine forests of New England, and pitch extracted from the piney woods of the South Atlantic. The progress of civilization has been called a struggle between human wants and natural resources. And no part of this age-long contest has been more clear cut than the effort of mankind to supply its need for wood.

Most of the industrially aggressive nations have lived in forested regions, and most of them have been liberal users of timber. The course of these nations in satisfying their requirements for forest-grown materials has usually run through three different stages. At first they have cut freely from their own virgin forests as long as the supply lasted. Then they have cast about for what they might barter from their neighbors. And finally they have settled down to the systematic growing of wood on all the land that could be spared for the purpose, still finding it necessary or convenient in many cases to import a substantial part of their national requirements from other countries whose virgin forests have not yet become depleted or whose timber culture produces an exportable surplus.

Man-grown timber, however, is costly, while timber stored up in nature's undrained warehouses is cheap. The source of supply is thus largely governed by the cost of growing timber at home as compared with the cost of hauling it from the nearest virgin forests still available for exploitation. In the long run, forestry is pitted against transportation.

[1] Reprinted by permission from Economic Geography, vol. 1, No. 1, March, 1925.

The United States is still in the first of these three stages. By far the greater part of the wood we use is still obtained from our own virgin forests. But the end of this supply is plainly in sight. The necessity is at hand of finding a new source of wood, either in timber culture on our own soil or in the forests of other countries. The consumption of timber in this country is so enormous that the problem assumes staggering proportions. We use annually about 12,000,000,000 cubic feet of saw-log timber, or nearly half of the quantity consumed in the entire world. Our use of all forest products, including pulpwood, railroad ties, mine timbers, and fuel wood, aggregates 22,500,000,000 cubic feet, or about two-fifths of the yearly consumption in the entire world.

Other countries which have likewise exhausted their virgin forests have found new sources of wood either in the practice of forestry or through imports from their neighbors, or by combining both of these methods, without sudden industrial upheavals or serious timber famines. Their consumption of forest products has been relatively small; the change was gradual and usually involved no great difficulty. The enormous use of wood in the United States, however, and its intimate relation to national living standards, manufactures, and basic industries like agriculture, mining, and transportation, make our problem far more serious. We must find, almost overnight, a fresh source of raw material sufficient to supply sixty or seventy million tons of forest products annually. Instead of a gradual industrial evolution, the change is coming with the suddenness of an economic crisis.

The forest history of the United States herself strikingly illustrates the relation of geography to timber supply. To the colonists and explorers of the seventeenth century, America appeared a vast, unbroken forest. Even after geographers had mapped the full extent of the prairies and western deserts they found that nearly half of her total land area, or more than 820,000,000 acres, was originally in forest. Although the export of timber products began in the early days of the Atlantic Colonies, for several generations the forest represented a barrier to settlement and migration rather than an economic resource. Nothing could have appeared more remote than a shortage of timber. About 200,000,000 acres of our original forest area has been cleared for cultivation and settlement, and the stumpage removed from three-fourths of it was destroyed for lack of a market.

When the manufacture of lumber at little sawmills, run by water power, became a fairly established industry, there was no lack of the finest raw material at their very doors. Lumber was moved but very short distances and its cost was exceedingly low. In 1736 pine lumber prices in New England were commonly around $5 per thousand

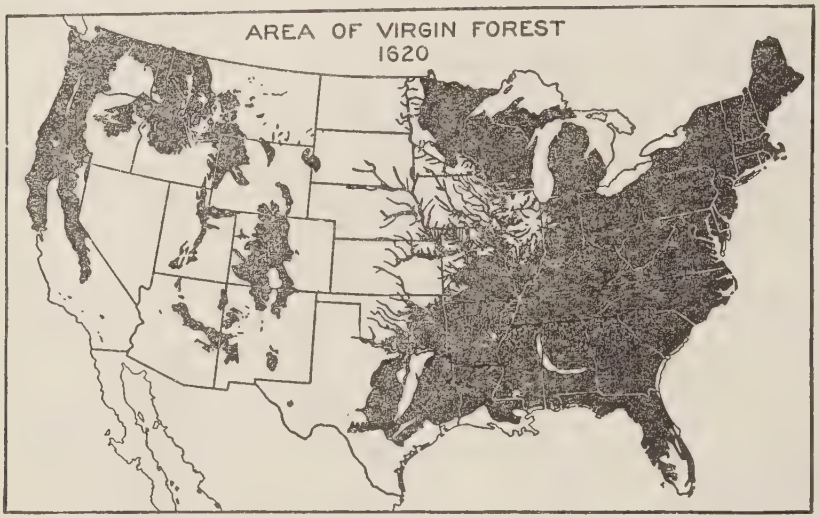
board feet. Between 1799 and 1834 pine lumber cut on the Kennebec River in Maine was sold on the Boston market for from $10 to $14 per thousand board feet. Slowly, very slowly, the frontier of virgin forest began to move back from the centers of population, and, as the sawmill followed its retreat, the element of transportation entered into the cost of forest products.

Up to the time of the Civil War, short and cheap lumber hauls, almost wholly by water, characterized our timber traffic. Lumber or logs moved down the Atlantic coast from Maine to Boston, about 225 miles, from the upper Hudson to New York, not over 200 miles, and from the shores of the Great Lakes into Buffalo and Chicago. The rafting of the Pennsylvania rivers rarely covered more than 400 miles; and the bulk of the products of "Penn's Woods" moved much shorter distances, as from Williamsport to Philadelphia. One or two or three dollars at the most paid the freight bill on a thousand feet, and the consumer's price was correspondingly low. Even up to 1902 the short local shipments from the Lake region held cargo prices on white pine boards at Chicago down to $16 per thousand feet or less.

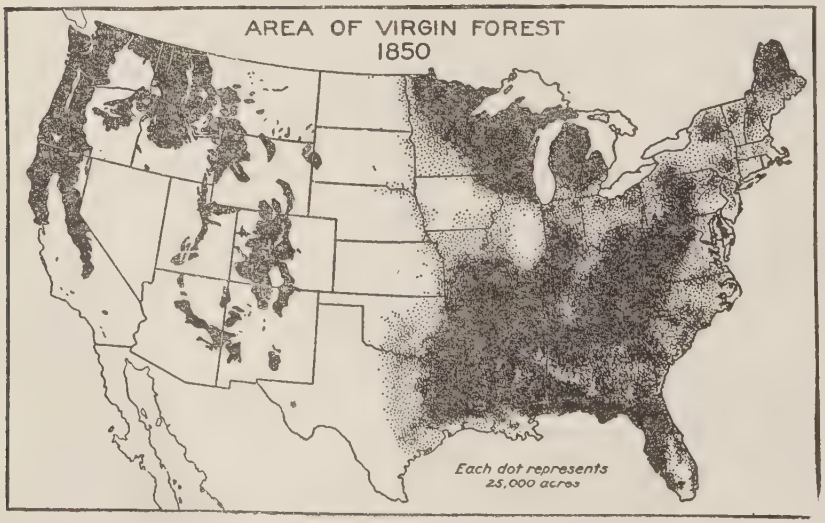
The change came with the railroad building and industrial expansion that followed the Civil War. Lumber manufacture ceased to be a village industry. It caught the spirit of "big business" and rapidly forged into the lead with large organizations, tremendous capitalization, and the efficient tools of quantity production. It reached out with unequaled driving power in manufacture and merchandising. It taught the American people to use wood in prodigious and unheard-of quantities. In 1840 the per capita consumption of lumber probably did not exceed 100 board feet. By 1906 it had become 516 board feet. Behind the sawmills came the paper mills, using more and more wood until it now forms 90 per cent of their raw material. Through their energetic attack upon the forests another great national appetite for wood has been created. The per capita consumption of paper has increased five fold since 1840. Then came the veneer plants, the distillation plants, the vehicle and agricultural implement factories, the makers of railroad ties and telegraph poles, and a hundred industrial developments with their greater or lesser demands for timber. The exploitation of virgin forests has been a foremost contributor to the economic growth of the United States during the last 70 years.

It was inevitable that our timber resources should shrink rapidly before this terrific onslaught. The story is told in the maps showing the approximate extent of the virgin forests in 1620, 1850, and 1920. The first 230 years of settlement and industrial expansion made relatively slight inroads. In the last 70 years the depletion

of our timber supply has gone on apace. And as the virgin forests disappeared, the relation of geography to timber supply has become more and more pronounced. It is summed up in the cost of trans-



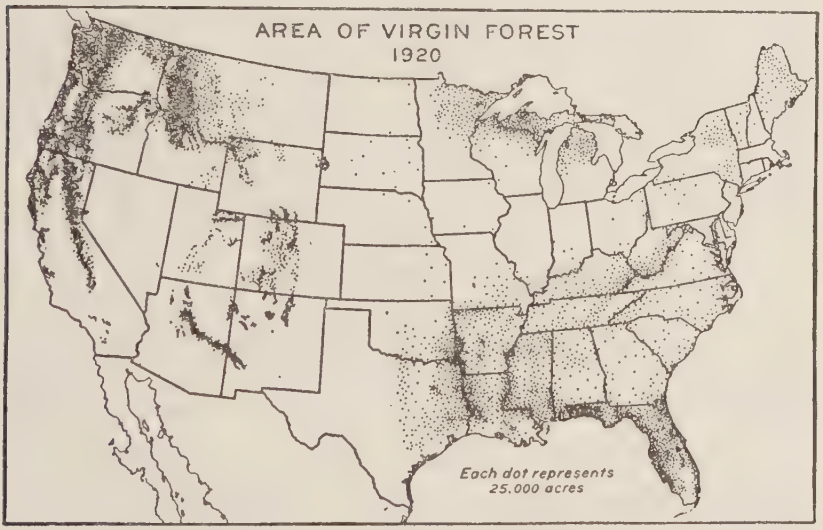
portation from the standing tree to the user of its products. From the economic viewpoint our forest history is a record of widening gaps between the consumer of lumber or paper and the source of his supply.



As long as Maine, New York, and Pennsylvania were the foremost lumber-producing States, lumber was cheap in the great markets of the country, primarily because the hauls were short and

largely by water. When the center of lumber manufacture moved to the Lake States in the eighties and nineties the era of the box car as a lumber carrier began. Freight rates were long tempered by water transportation on the Lakes, through the Erie Canal, and down the Mississippi; but at that it cost $6 or $7 per thousand feet to ship lumber a thousand miles from Saginaw to New York by water, or treble the old rate on Hudson River pine. As steadily as the more accessible virgin forests went through the hopper, the railroads gained ascendency in lumber traffic, the hauls lengthened, and the average retail prices rose from one level to another.

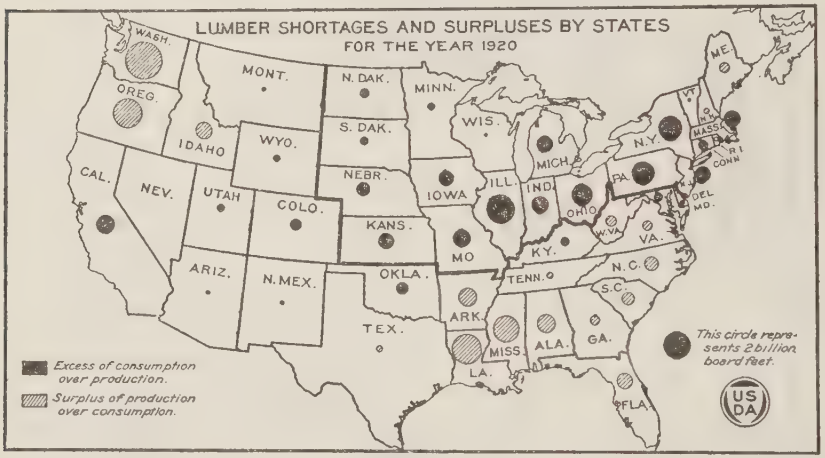
During and following the nineties the pineries of the Lake States rapidly approached exhaustion and the center of the national supply of softwood lumber shifted to the South. Rail shipments in



excess of 750 miles and freight bills of $8 or $10 or more per thousand board feet became common. As southern pine gradually secured control of the Chicago market, lumber prices advanced to 75 or 100 per cent beyond the old rates fixed by water transportation from Michigan or Wisconsin mills. Southern lumber moved 1,100 miles to Pittsburgh and 1,500 miles to Boston, at freight rates which, since the World War, have ranged from $12.50 to $15 per thousand feet. Retail prices necessarily climbed to a higher level, but only as a stepping stone to what has followed as the last chapter in the exploitation of our virgin forests is being written.

The virgin pineries of the South covered 130,000,000 acres and contained probably 650,000,000,000 feet of saw timber. They formed one of the richest reservoirs of softwoods on the earth's surface, and

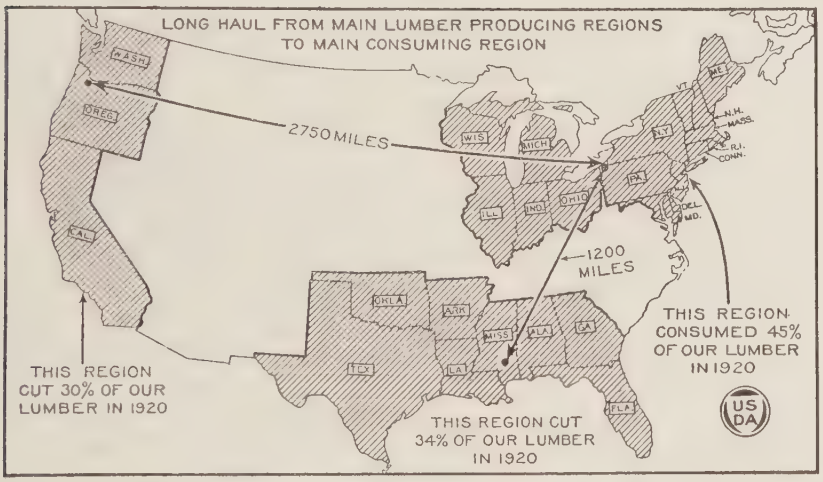
for the past 30 years they have been the mainstay of the eastern and central lumber markets of the United States. But the process of timber depletion is running its course in the South as it has previously been run in the Lake States and the Alleghenies. The production of southern pine lumber passed its peak in 1916, and the last great migration of American sawmills is under way—across the Great Plains to the virgin forests of the Pacific coast. In 1920 over 600,000,000 board feet of western lumber was shipped to New England and over 1,200,000,000 feet was marketed in Illinois, Michigan, Wisconsin, and Minnesota. In 1922, 33½ per cent of our entire lumber cut was manufactured on the Pacific coast as compared with 40 per cent in the Southern States. Western lumber is now moving in a steadily increasing volume 2,000 or 2,300 miles by rail to the



Middle West at a freight cost of $17 or $18 per thousand board feet, and 7,000 miles by sea and the Panama Canal to northern Atlantic ports at a charter rate of $16 or $17 per thousand feet. Lumber manufactured on Puget Sound is now, indeed, moved by steamer to Chesapeake Bay and reshipped inland, past the old sawmill towns of the Alleghenies, as far as Pittsburgh and Cincinnati.

Every year the cost of transportation enters more largely into the lumber bills paid by the American home builder or the American factory. Two-thirds of the lumber which we use is consumed in the Central and Eastern States. The lumber traffic in 1920 exceeded 1,660,000 carloads and cost, in freight and charters, over $250,000,000. The average carload was hauled 485 miles. Between 1914 and 1920 the average rail haul on lumber was lengthened by more than 30 per cent, and the total yearly freight paid on lumber shipments advanced $100,000,000.

These mounting costs for transportation underlie the rise in lumber prices. Costs and profits in retail distribution tend to pyramid upon every increase in freight. And as the sawmills become more largely concentrated in distant and restricted regions, the competitive movement of lumber into consuming markets is curtailed. Retail prices seldom fail to advance in response to such opportunities. The story of lumber prices in a group of Minnesota towns is illuminating. In 1905, 91 per cent of their supply came from the Lake States. The average freight cost was $3.25 per thousand feet and the average selling price was $26. In 1921 over 92 per cent of the lumber handled in these towns came from the Pacific coast. The average freight bill was $18.12 per thousand feet and the average selling price $53.58. Transportation cost had increased from 12½



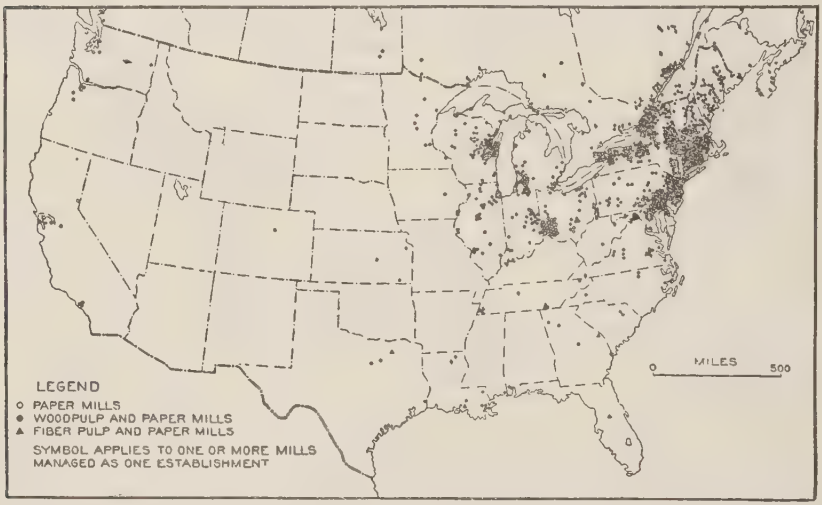
per cent to 34 per cent of the retail price, but the actual cost to the consumer, it will be noted, had more than doubled.

In fact, the prices paid by the average user of every-day construction lumber the country over have more than doubled within the last 12 years. The very freight paid on lumber is now often more than its delivered price 30 years ago. Hence it is not difficult to understand why lumber prices have advanced during the last 80 years three and a half times as rapidly as the index price based upon all staple commodities. It took $510 in 1921 to buy as much lumber—and poorer lumber at that—as $100 bought in 1840.

The story of the American paper industry is somewhat different but reflects no less clearly the extent to which our virgin forests have been depleted. Paper manufacture requires exceptionally heavy plant investments. Hence it has not followed the retreating frontier of virgin forests to nearly the same extent as have the sawmills, but

has remained largely concentrated in the northeastern States. As a consequence the raw material available on American soil has been wholly unable to sustain our increasing consumption of paper. Of the 8,000,000 tons used in the United States in 1922, 53 per cent came from foreign countries in the form of pulpwood, manufactured pulp, or finished paper. Thirty-seven per cent was imported from Canada alone, including over 1,000,000 cords of raw pulp wood. The cost of the pulp wood delivered at American plants, much of which is now hauled excessive distances, has probably increased even more rapidly than the price of lumber. In satisfying its needs for this important forest product, therefore, the United States has already outstripped the resources of her own virgin forests. She has been driven to the paper and pulp-wood markets of the world.

PAPER AND PULP MILLS OF THE UNITED STATES, 1922


LEGEND
○ PAPER MILLS
● WOODPULP AND PAPER MILLS
▲ FIBER PULP AND PAPER MILLS
SYMBOL APPLIES TO ONE OR MORE MILLS MANAGED AS ONE ESTABLISHMENT
0 MILES 500

The stern facts of geography have largely controlled these past developments in our forest industries and in the cost of their wares to the American consumer. The true measure of timber supply is not quantity but availability. Sixty per cent of all the wood that is left in the United States and 75 per cent of its virgin timber lie west of the Great Plains, whereas two-thirds of the population and an even larger proportion of our agriculture and manufactures are east of the Great Plains. The forests bordering the Pacific coast contain over a trillion feet of virgin stumpage. At the most, they will not supply our present consumption very long, but already the unbalanced geographical distribution of this resource is creating well-nigh famine prices in the parts of the United States where forest products are used in the largest quantities. Dependence upon

the softwood forests of Siberia as the principal source of supply would differ from our present situation only in degree.

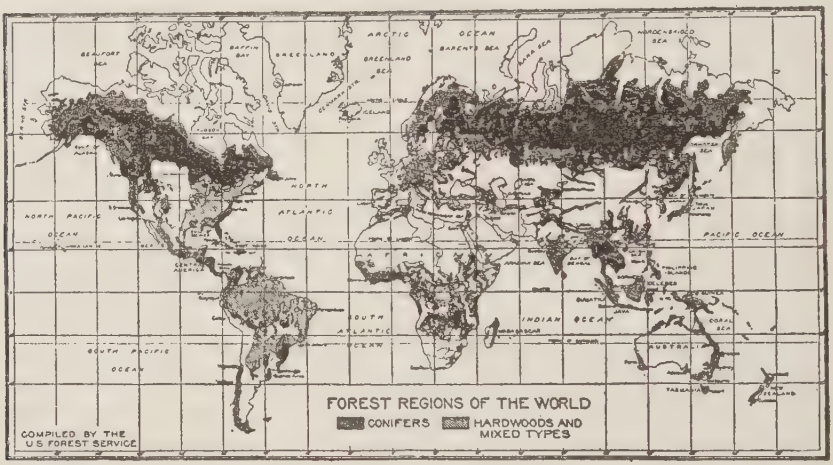
And as geography controls the cost of the products of virgin forests when they reach the ultimate consumer in Massachusetts, Illinois, or Florida, so will geography control the substitution of other sources of timber supply. Most of the other countries have progressed from one stage to another in their source of wood more or less as single geographical units. In the United States the distances are so great and the local conditions so diverse that this transition is bound, for some time to come, to be regional rather than national. We have already seen that, owing to the concentration of the paper industry in the northeastern States, more than half of our consumption of wood fiber products is now drawn from foreign sources. And by the same token the exigencies of the portions of the country farthest removed from the dwindling frontier of virgin forests are driving them to a new source of wood—namely, the timber crop.

Forestry is the economic competitor of transportation. As long as cheap virgin stumpage available at no great distance dominated our lumber and paper markets there was no place in the economic scheme of things for systematic timber growing. But once the cost of transporting forest products from the nearest virgin sources exceeds the cost of growing them at home, timber culture not only becomes economically feasible but sooner or later is impelled by purely commercial forces. This is just what is taking place to-day, to a limited degree, in New England, New York, Pennsylvania, and New Jersey; and, to a still more limited degree, in the South. Second-growth white pine in New England, 30 or 40 years old, is worth from $15 to $20 per thousand board feet standing in the woods. Second-growth southern pine of the same age brings from $8 to $12 on the stump. With such returns before them and with timber values constantly moving upward, hard-headed business men realize that forestry pays. One might almost plat the process by a series of geographical zones, and show that when the freight rate into any consuming region from the nearest large supply of virgin timber passes the $10 or $12 mark, an economic basis for timber cropping is afforded and forestry slowly finds a place in the use of land.

Forest conservation in the United States hitherto has been largely a matter of public ownership of timberland and public policies based not upon costs and profits but upon foresight of coming national necessities. To-day it is percolating down into the counting-house and the directors' board room. The illusion of inexhaustible virgin forests has spent itself. Wood-using industries recognize the alternatives which they face—producing their future raw material

or passing out of existence. A committee of pulp and paper manufacturers is studying ways and means of perpetuating their industry on American soil. A committee of turpentine and rosin producers is going to France to learn the naval stores forestry of the Landes and how it may be applied to our southern pineries. These are signs of the times.

The shortage of available virgin timber is growing more and more critical every year. It can not be emphasized too strongly that the seriousness of this problem is in proportion to our enormous use of wood, to our unparalleled economic and social dependence upon forests. To solve this problem with even meager success, every resource of American ingenuity and foresight must be employed.

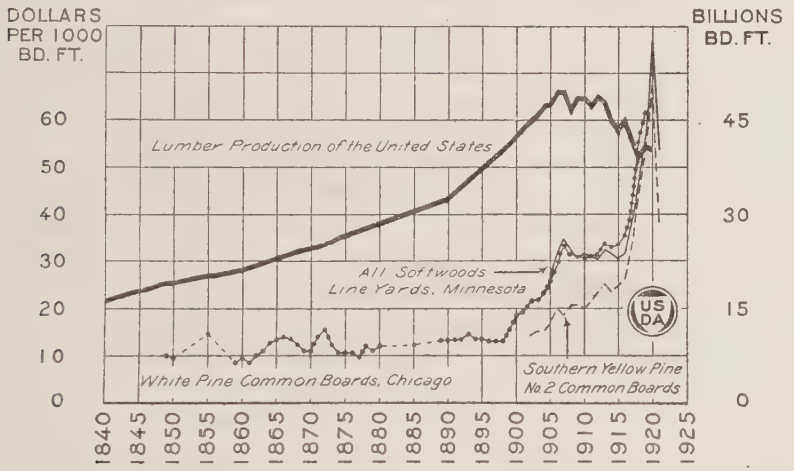


Like the other nations in similar plight, we must barter for all the timber we can secure from our neighbors. The prospects in this direction, however, are not encouraging. Our present exports and imports of lumber and other forest products nearly balence. The imports can undoubtedly be increased somewhat, particularly of paper from Canada and of lumber in limited quantities from certain Canadian provinces and from Mexico. The hardwood forests of South America and the softwood forests of Siberia hold out possible sources of relief. But a number of other industrially aggressive nations are in the same situation as the United States. A recent survey[2] of the principal forest resources and wood-using countries of the world shows that the markets of the whole earth are short of raw materials for paper and construction lumber, and that the accessible supply of timber, particularly of coniferous

[2] Zon and Sparhawk, Forest Resources of the World, 1923.

timber, is not adequate to meet the requirements of modern civilization. The cost of transporting Asiatic or South American lumber to the United States, added to prices at the source fixed by keen international competition, would be well-nigh prohibitive for ordinary construction or industrial purposes.

Nevertheless, we must get all the foreign wood that we can to tide over the lean years, and we must go after it intelligently and systematically. For one thing, a thorough study should be made of the resources available in the hardwood forests of Central and South America and their utility for the replacement of our rapidly waning supply of native hardwoods. For another thing, it should be our policy in foreign trade and tariff making to encourage imports of timber and timber products. The United States can ill



afford to place barriers around its depleted forests and hungry lumber markets.

Undoubtedly we must and will learn to use less wood. The high cost of lumber has already decreased its per capita consumption in the United States about 40 per cent below the peak of 1906. Steel, cement, and clay products have been substituted for much of the construction lumber formerly used; and coal, oil, and electricity have taken the place of much fuel wood. These substitutions are increasing, as wood becomes more dear; and it is well that they should. On the other hand, the use of wood is constantly widening as the chemist and engineer discover new methods of converting or fashioning it for modern requirements. Wood is now manufactured into grain alcohol and artificial silk, even into baking powder and electrical conduits. The field for wood-fiber products is constantly enlarging. Notwithstanding the substitution of other ma-

terials and the curtailed use of wood for many of its old functions, the total drain upon our forests thus far has not materially lessened. The danger lies not in reducing the use of wood where satisfactory substitution is possible, but in the growing shortage for many essential needs for which there are no substitutes. In most of the industrial countries of Europe the per capita consumption of wood is not diminishing but increasing; and the United States can not expect permanently to follow a different course if it is to hold its living standards and retain its industrial leadership.

One of the most essential constructive remedies is to reduce the drain upon our forests by reducing the waste in the manufacture and use of their products. The very abundance and cheapness of virgin timber in the United States has bred wasteful methods of logging, manufacture, and refabrication which are yielding but slowly to the pressure of scant supply and high costs. The general application of even our present knowledge of waste elimination in logging, milling, and refabricating lumber, in timber preservation, in the conversion of wood into fiber products and the like, would reduce the current drain upon our forests by 20 or 25 per cent. And we still have much to learn before all the possibilities of economy in the use of our forests are fathomed. The elimination of preventable losses from forest fires and from destructive insects and tree diseases would save an enormous total of useful timber. A cord of wood saved is equal to a cord of wood grown. And one of the most obvious things that should be done with all possible dispatch is to conserve our existing timber supply to the last foot by research in the conversion and use of forest products on an adequate scale, accompanied by wide dissemination of its results through the forest industries and forest consumers.

After everything else has been said, no solution of our forest problem is possible without the generous growing of trees. We must come, in the last analysis, as every other country treading the same path has come, to forestry as the necessary and economic employment of much of our land. This solution is as complete as it is inevitable. Intensive timber culture on the 470,000,000 acres of forest land in the United States, timber culture on a par with that of Germany, France, and Scandinavia, can produce a yearly crop equivalent to more than all the wood which the United States now consumes. There will be a margin of 20 per cent or more to take care of the greater requirements of the future. The only question is how quickly can this be brought to pass and how much national suffering must be endured before a perpetual supply of timber is assured on our own soil. National habits in the use of land and its resources change slowly; and at best we must travel a slow and painful road before the goal is reached.

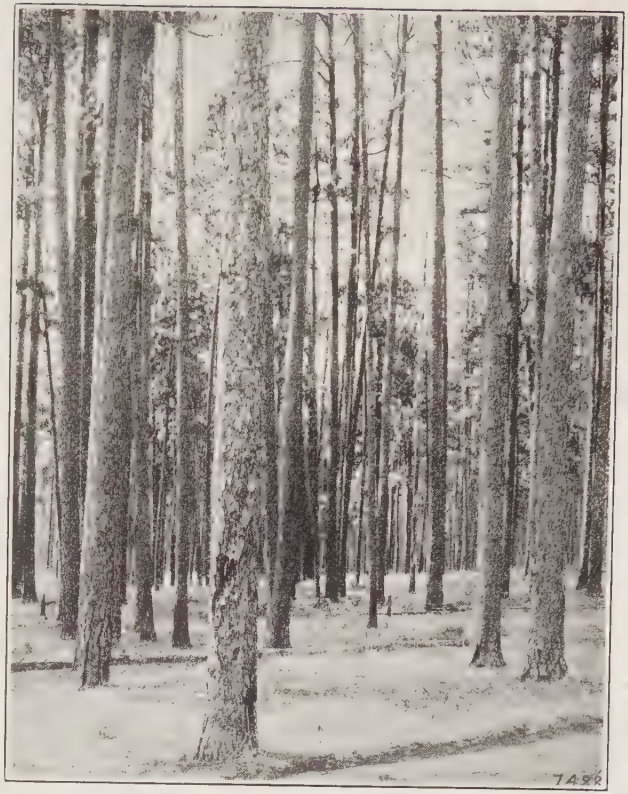
Underlying this whole question is one of the outstanding facts of the economic geography of the United States—namely, that one-fourth of her soil remains to-day, after three centuries of settlement and expanding agriculture, forest land. There is small prospect that the area available for growing trees will be reduced materially, if at all, for many years to come. While the inroads of the farm are continuing here and there, the great tide of forest clearing for cultivation seems largely to have spent itself. For many years indeed, the abandonment of farm land in forest-growing regions of the older States has practically offset new clearing on the agricultural frontier. Farm economists prophesy that still larger acreages will be available for timber culture in the future than at present.

Wholly aside from the need for timber, the problem of keeping one-fourth of the soil of the United States productively employed is one of no small urgency in the national economy. The idleness of cut-over land, following the migration of the sawmills, has already been a widespread cause of depopulation, decline in taxable values, and general rural bankruptcy. In the busiest timber manufacturing regions of a few decades ago, there remains to-day over 80,000,000 acres of unproductive and unused land. No country can afford such wastage.

Forestry not only is the only way to reestablish an adequate source of timber in the United States. It is the only way to utilize a large part of her land, to maintain a vigorous rural population with industries, communities, and good roads. On both counts, forestry should become part and parcel of our program of land use.

1. LARCH TIMBER, KOOTENAI NATIONAL FOREST, MONTANA

Photograph by K. D. Swan. Courtesy U. S. Forest Service



2. LONGLEAF YELLOW PINE, VERNON COUNTY, LOUISIANA

Photograph by E. J. Davison. Courtesy U. S. Forest Service

1. YOUNG STAND OF WESTERN HEMLOCK, SNOQUALMIE NATIONAL FOREST, WASHINGTON

Photograph by A. G. Varela. Courtesy U. S. Forest Service

2. SECOND GROWTH PINES, CARROLL COUNTY, NEW HAMPSHIRE

Photograph by W. D. Sterrett. Courtesy U. S. Forest Service

1. YOUNG STAND OF SLASH PINE, SLIDELL, LOUISIANA

Photograph by W. R. Mattoon. Courtesy U. S. Forest Service

2. LUMBER VESSELS, PORT BLAKELY, WASHINGTON

Photograph by Gifford Pinchot. Courtesy U. S. Forest Service

THE HISTORICAL GEOGRAPHY OF EARLY JAPAN[1]

By Carl Whiting Bishop

Smithsonian Institution

[With 9 plates]

It is matter for congratulation, in view of the steadily growing interest in the question, that the accumulation of evidence from various sources begins at length to throw some definite light on the origin of the Japanese people. Much confusion has existed on this subject hitherto, owing mainly to the fact that the work of investigators along different lines had been insufficiently collated and correlated, while at the same time the methods of interpretation were not altogether free from fault. A solution of the problem is not to be attained by a study of conditions and events in the Japanese islands alone. The same causes which have brought about the various contacts, friendly or hostile, between Japan on the one hand and eastern Siberia, Korea, Shantung, and the southeastern Chinese littoral on the other, during the past three decades, have been at work without intermission ever since the first settlement of man in this portion of the globe. The developments, political, social, economic, whose course we have followed with such close attention during the past few years are but the latest phase of a process whose beginnings are lost in the darkness of prehistoric time. It is thither that we must trace them if we would arrive at anything like a right comprehension of the foundation upon which rests the national life of Japan.

FIRST CONTEMPORARY ACCOUNTS OF THE JAPANESE PEOPLE

Derived without exception from Chinese sources[2] are our first contemporary accounts of the Japanese people, 2,000 years ago. The region at that time occupied by their various tribes embraced not what we think of as the Japanese islands, but only their westernmost portions, together apparently with the southern end of the

[1] Read at the joint meeting of the Association of American Geographers and the American Geographical Society, April, 1922. Reprinted by permission from the Geographical Review, vol. XIII, no. 1, January, 1923.

[2] See for an account of these, James Murdoch: A History of Japan, Yokohama, 1910, vol. 1, pp. 31 et seq. For accounts of what the Chinese writers have to say regarding the early Japanese, see E. H. Parker: Ma-Twan-Lin's Account of Japan up to A. D. 1200, Trans. Asiatic Soc. of Japan, vol. 22, 1894, pp. 35–68; also, Albert Tschepe: Japans Beziehungen zu China seit den ältesten Zeiten bis zum Jahre 1600, Yenchow-fu, 1907.

Korean peninsula and the large island known to us as Quelpart, lying out in the Yellow Sea. As will be seen, it was not until the seventh century of our era that the Japanese became in reality wholly an island people. Hence insularity was far from being the geographical factor of most weight in their early development. Of vastly greater significance was the fact that during their formative period they were in such close touch with the various civilized communities of the continent.

PEOPLING OF THE JAPANESE ISLANDS

The effect of winds and currents was also much slighter than is often claimed. The sail was still quite unknown in Far Eastern waters in those prehistoric ages when the peopling of the Japanese islands was going on, so that there was no way in which the monsoons could exert any particular influence upon the course of migration.[8] And the southern element, so clearly apparent in both the people and their culture, came not from those equatorial regions whence flows the Japan current but from a direction at right angles to it, the seaboard of China, in days before Chinese civilization had yet reached the coast. Those who speak of a Polynesian or a Malayan strain in the Japanese ignore entirely the historical aspect of the problem; the great Polynesian diffusion did not take place until long after the emergence of the Japanese people, while the Malays do not appear on the scene until later still. The real effect of the southwest monsoon and the warm tropical current has been a climatic one. To them it has been due that the type of culture developed during prehistoric times in the southeastern coast lands of the continent could find in the southern and western portions of the Japanese Archipelago those conditions of warmth and humidity requisite to its survival and further development.

Of Paleolithic man in Japan there has so far appeared absolutely no trace, and it is altogether likely that the islands, together with the east of Asia generally, remained unpeopled until geologically very recent times.

The earliest inhabitants of Japan of whom we have any knowledge were the ancestors of the existing Ainu of Yezo (Hokkaido), who at one time occupied the entire archipelago, remaining in undisturbed possession during a period which may well have extended over several thousand years.

[8] On the late introduction of the sail in Japanese waters, see B. H. Chamberlain (transl.): Ko-ji-ki, or Records of Ancient Matters, Trans. Asiatic Soc. of Japan, vol. 10, 1882, Supplement; reference in introduction, p. xxv; H. A. C. Bonar: On Maritime Enterprise in Japan, ibid., vol. 15, 1887, pp. 103–125; reference on pp. 107 and 111; W. G. Aston: An Ancient Japanese Classic (The Tosa Nikki, or Tosa Diary), ibid., vol. 3, part II, January–June, 1875, pp. 121–130; reference on p. 124.

FIG. 1.—Map to illustrate geographical relations in early Japanese history. Numbers indicate the main cultural *foci:* 1, northern Korea (the kingdom of Chao-hsien is here shown in its later stages, earlier it extended across the Yalu basin); 2, southern Korea; 3, Kyushu; 4, Izumo; 5, Yamato. Letters have reference to successive Ainu frontiers. The conquest and absorption of the Ainu had pushed the Yamato frontier as far eastward as the Lake Biwa region (A) before the close of the prehistoric period. The line B–B represents the next great advance, just at the dawn of the historical period, and C–C the frontier as it existed about the time of the loss of the continental possessions of the Yamato. The line D–D was reached by the Japanese about the beginning of the eighth century, and the occupation of the main island may be regarded as completed, in its broad outlines, by the close of the tenth century. Scale of map approximately 1 : 22,500,000

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At length, probably far back in the first millennium before Christ, if not indeed earlier still, there began a fresh invasion of the Japanese islands, this time by peoples belonging to various branches of the great Mongoloid stock, from eastern Siberia to the south Chinese littoral, with probably in the latter case a slight Negrito admixture. The result of the minglings in varying proportions between these newcomers and their predecessors forms to this day the great bulk of the Japanese population.[4]

Finally, commencing not long before our era and recurring at intervals for several centuries, there was a series of immigrations of northern Mongoloids—Chinese and Koreans in the historical sense—whose influence, physical but more particularly cultural, has been largely confined to the upper strata of Japanese society.

THE ANCESTRAL AINU

The first of these races, that of the ancestral Ainu, seems to have reached the Japanese islands in at least three successive waves, perhaps separated by long intervals of time.[5] Recent studies have shown that it was divided into several subtypes, at least two of which appear to survive in the existing Ainu. That the language of this ancient race was essentially that still spoken by its surviving representatives in the island of Yezo is indicated by the fact that place names occur all over the Japanese islands, from end to end, and possibly even in the Loochoo group, which can only be explained in terms of Ainu speech.[6]

Regarding the origin of this primitive people we are still wholly in the dark. Some have seen in them a kinship to the prehistoric European race known as that of Furfooz-Grenelle. Language tells

[4] Regarding this question of the composition of the Japanese people, see the following: K. Hasebe: Study upon the Human Bones found at Kō in the Second Excavation, Rept. upon Archaeol. Research in the Dept. of Literature, Kyoto Imperial University, vol. 4, 1919–20; idem., The Excavation of the Shell Mound at Tsukumo, a Neolithic Cemetery in the Province of Bitchū, ibid., vol. 5, 1919–20; H. Matsumoto: Notes on the Stone Age People of Japan, Amer. Anthropologist, vol. 23 (N. S.), 1921, pp. 50–76; Katsuro Hara: An Introduction to the History of Japan, New York, 1920, pp. 48 et seq.; H. ten Kate: Notes détachées sur les Japonais, Bull. et Mémoires Soc. d'Anthropol. de Paris, ser. 5, vol. 9, 1908, pp. 178–195; E. Baelz: Prehistoric Japan, Ann. Rept. Smithsonian Inst. for 1907, 523–547; Frank Brinkley: Primeval Japanese, ibid., 1903, pp. 793–804.

[5] See regarding these ancestral Ainu, in addition to the papers by Hasebe and Matsumoto, already cited, N. G. Munro: Prehistoric Japan, Yokohama, 1911, pp. 37–292 and passim; also Hara, op. cit., pp. 31 et seq.

[6] Regarding Ainu place names in Japan, see B. H. Chamberlain: The Language, Mythology, and Geographical Nomenclature of Japan Viewed in the Light of Ainu Studies, Tokyo, 1887; also, Romyn Hitchcock: The Ainos of Yezo, Japan, Rept. U. S. Nat. Museum for the year ending June 30, 1890, pp. 429–502; reference on p. 434.

us nothing; for, aside from loan words from neighboring tongues, the Ainu speech stands entirely isolated.[7] Physically there is no evidence of connection with the Mongoloid family, save for such interminglings as have taken place in relatively recent times. Many investigators have regarded the Amur region of Siberia as that from which this ancient race entered Japan. The fact should not be overlooked, however, that individuals of Ainu type are by no means unknown in Korea, while a possible relationship has also been suggested between the Ainu and the pre-Dravidian tribes of India, or even with the natives of Australia.

Perhaps we may say, in the light of all the available evidence, that the few thousand Ainu still remaining, as well as the related stocks inhabiting Japan in days prior to the advent of Mongoloid man, represent an extremely ancient generalized human type from which more than one of the wavy haired and heavily bearded races of Europe and southern Asia have been specialized.[8]

Of the culture of the ancestral Ainu, thanks to the somewhat extensive excavations of the past few years, we know considerably more than we do of their origin. They were already in the Neolithic stage as far back as they have been traced. They manufactured polished stone implements and a highly interesting and very ornate type of pottery, made, of course, without the aid of the potter's wheel. They seem to have derived part of their subsistence from the cultivation of millet, although doubtless dependent mainly upon hunting, fishing, and various wild vegetable products. Of domestic animals, with the exception of the dog, they were entirely ignorant. In summer they lived in rough huts and in winter in earth-covered lodges constructed either partly or wholly underground. Dwelling mainly on the coast and knowing how to make large dugout canoes, they were fearless seafarers, hunting the whale as well as smaller marine animals and, in later times, meeting the fleets of war boats of the invading Japanese in fiercely contested naval combats from which the newcomers by no means always emerged victorious.

Of their social, political, and military organization we can infer but little. It seems clear, however, that in these respects they were scarcely if at all behind the earlier comers of Mongolian extraction who settled among them; for they were able to keep the latter pretty

[7] Berthold Laufer: The Vigesimal and Decimal Systems in the Ainu Numerals: With Some Remarks on Ainu Phonology, Journ. Amer. Oriental Soc., vol. 37, 1917, pp. 192–208; reference on p. 205.

[8] On the classification of the Ainu, see George Montandon: Notice préliminaire sur les Aïnou, Archives Suisses d'Anthropologie Générale, vol. 4, No. 3, 1921, pp. 233–246; reference on p. 242; also, A. F. Chamberlain: The Japanese Race, Journ. of Race Devel., vol. 3, 1912–13, pp. 176–187; reference on p. 182.

closely confined to the extreme western portions of the Japanese Archipelago for many centuries. It was simply and solely the stubborn geographical fact that the Mongoloids always had free access to the civilizing influences emanating from the continent, while the Ainu had not, that inevitably swayed the balance in favor of the former, and in the long run sealed the fate of the aborigines as a distinct ethnic entity.

EARLY MONGOLOID INVASIONS

We know from various sources that southeastern Asia prior to the rise of the Chinese civilization was occupied by a race of Mongoloid stock, akin to the existing peoples of Indo-China and Indonesia, whose original culture, of a generalized Neolithic type, had taken on a distinctly southern and maritime aspect. That it was in contact, however, with more northern regions is shown by the occurrence both in Shangtung and in Japan of the grooved stone ax, a type of implement found likewise in the North Pacific area.[9] The discovery again both in China and in Japan of the peculiarly shaped objects known in the latter country as *seki-bo*, or "stone clubs," also indicates a former widespread community of culture, extending in this instance even to the Ainu.

Socially, this southeastern Asiatic culture seems to have been characterized by descent in the female line, by seasonal mating festivals, and, at least in the ruling families, by brother-and-sister marriage.[10] The economic life, based primarily upon fishing, with doubtless some hunting, had been enriched before the close of the Neolithic period by the acquisition of various food plants, cultivated with the aid of the hoe alone. Among methods of bodily ornamentation were blackening of the teeth and tattooing. But little clothing was worn, save in cold weather; and the habit of promiscuous bathing, with a total indifference to bodily exposure, was general. No domestic animals other than the dog and the fowl appear to have been known. In the absence of metals, great use was made of bamboo, although stone and bone were also utilized in various ways. There is some reason to believe that the spear rather than the bow was the weapon most commonly in use. As befitted a culture essentially amphibious in type, large canoes were made, each usually ornamented at the bow with the carved head

[9] On this question of the grooved ax, see Berthold Laufer: Jade: A Study in Chinese Archaeology and Religion, Field Museum of Nat. Hist. Publ. 154 (Anthropol. Ser., vol. 10), Chicago, 1912, pp. 50 et seq.

[10] For its former existence among the Japanese, see B. H. Chamberlain: Ko-ji-ki, Intro., pp. xxxviii and xlv; W. G. Aston: Shinto (The Way of the Gods), London, 1905, p. 91.

of a crocodile or an alligator.[11] The religion was one of nature worship, with a strongly anthropomorphic trend and a highly interesting body of folklore. Possibly as a result of the matrilineal organization of society, the principle of reproduction and growth received special veneration, and goddesses were particularly in evidence. Ancestor worship, where found at all in this area, appears only late and then as a consequence of the introduction, among the higher classes, of a patriarchal type of family in imitation of the Chinese. Practically all these culture elements are traceable in Japan, some of them surviving to this day, while others have disappeared only in comparatively recent times.

From the end of the promontory of Shangtung to the corresponding projection on the opposite coast of Korea it is only a trifle over a hundred miles—a stretch of sea easily negotiable by such inveterate sea rovers as were the Neolithic coast peoples of eastern and southeastern Asia. The strait between Korea and Japan is almost exactly the same distance across; and here there are islands where early voyagers could conveniently break their journey. It seems likely for a number of reasons that the colonization of Japan by the Mongoloid peoples of the neighboring continent took place largely by way of Korea. Probably, however, even within the Neolithic period a good deal of migration went on also directly across the Yellow Sea. The distance here is something under 500 miles, with the lofty island peak of Quelpart, already mentioned, forming a natural stepping-stone.

This migration of peoples into Japan, to be properly understood, must be viewed as a phase of that great ethnic movement which brought about the colonization by the so-called yellow-brown races of so much of the enormous area extending from Japan on the east to Madagascar on the west. When this process began, we are as yet unable to say; but it seems not unlikely that one of the contributing factors was the pressure generated by the slow expansion coastward of the Chinese in the second and first milleniums before Christ. The disturbances set up, for example, by the Chou conquest of the Yellow River Basin, about the eleventh century before our era, were felt far and wide and must have led to much shifting of

[11] A crocodile (*Crocodilus porosus*, or "Estuarine crocodile") seems to have been found anciently all along the southeastern Chinese coast at least as far north as the Yangtze delta, although now practically exterminated; cf. Arthur Stanley: The Collection of Chinese Reptiles in the Shanghai Museum, Journ. North-China Branch of the Royal Asiatic Soc., vol. 45, 1914, pp. 21–31, reference on p. 23.

A true alligator (*Alligator sinensis*), smaller than the American forms and rarely exceeding 6 or 7 feet in length, still occurs in the Yangtze, although it is by no means common; cf. A. A. Fauvel: Alligators in China, ibid., vol. 13 (N. S.), 1878, pp. 1–36 f.

peoples both by land and by sea.[12] Again, when the "barbarian" kingdom of Yüeh, corresponding roughly to the modern Chinese province of Chekiang, overthrew the rival state of Wu, in the Yang-tze embouchure region, in 473 B. C., the ruling class of the latter are said to have made their escape to certain islands to the eastward, which can hardly have been other than the western portion of the Japanese groups.[13]

The earliest distinct reference to Japan in the Chinese writings, however, is one in the work known as the Shan Hai Ching, to the effect that the northern and southern Wo are tributary to Yen, a Chinese feudal kingdom at the head of the Gulf of Chihli.[14] Inasmuch as Yen ceased to exist as an independent state in the year 226 B. C., this notice carries us back at least as far as the middle of the third century before our era, and possibly even farther still, since we know that Yen had been sending out exploring expeditions by sea as early as the reign of King Wei (378–343 B. C.).[15] We need not infer, however, that an actual conquest by Yen of any part of the Japanese islands ever took place. As is well known, it was long an official convention in China that all outsiders resorting to her for purposes of trade came to her as "tribute bearers." It may therefore be fairly concluded from the passage in the Shan Hai Ching that the two Wo peoples were in the habit of sending trading parties to Yen which had the cognizance of its government in days when foreign commerce was kept as far as possible a close state monopoly.

Precisely where the two Wo are to be sought, it is impossible to say. Perhaps the northern branch inhabited the lower extremity of the Korean peninsula;[16] or, on the other hand, they may both have dwelt in western Japan. That the southern, or "Great," Wo were located in Kyushu seems quite clear. For another name applied to their country by Chinese writers is that of Ye-ma-t'ai.

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[12] Compare C. W. Bishop: The Geographical Factor in the Development of Chinese Civilization, Geogr. Rev., vol. 12, 1922, pp. 19–41.

[13] Albert Tschepe: Histoire du royaume de Ou (1122-473 av. J.-C.), Variétés Sinologiques, No. 10, Shanghai, 1896, p. 156, quoting from the T'ung-chien K'ang-mu. Early Chinese writers describe an enchanted isle in the Eastern Sea where the customs are like those of the people of Wu; see E. H. Parker: Early Japanese History, The China Review, vol. 18, 1889–1890, pp. 212–248; reference on p. 214.

[14] W. G. Aston: Early Japanese History, Trans. Asiatic Soc. of Japan, vol. 16, 1888–89, pp. 39–75; reference on p. 40 and in note 5. While the date of composition of the Shan Hai Ching has not yet been settled beyond dispute, the weight of evidence points toward the third or second century before Christ, although it undoubtedly contains much earlier elements.

[15] For the maritime explorations of Yen, see Édouard Chavannes, Mémoires Historiques de Se-ma Ts'ien (5 vols., Paris, 1895–1905), vol. 3, pp. 436 et seq.; on the conquest of Yen by Ch'in Shih Hwang-ti in B. C. 226, ibid., vol. 4, p. 150. Inasmuch as the state archives of Yen, like those of practically all the rest of the ancient Chinese feudal states, have been lost, we know nothing regarding the details of her maritime explorations.

[16] Cf. E. H. Parker: China: Her History, Diplomacy, and Commerce, from the Earliest Times to the Present Day, 2d ed., London, 1917, p. 21.

This region, we are told, lay to the south of Korea—somewhere, that is to say, in the island of Kyushu—and contained a hundred petty kingdoms, all subject to the Ta Wo Wang, or great king of the Wo. It is further described as a maritime region with a late Stone Age culture, lying nearly due east of what is now the Chinese province of Chekiang and enjoying so mild a climate that vegetables were grown both winter and summer.[17]

Now the winters of the Japanese Pacific seaboard are mild, it is true, thanks to the Japan Current. But nowhere are they mild enough to admit of the winter ripening of crops, save in certain favored localities of Shikoku and Kyushu; and of Shikoku in this connection there is no question. Yet several modern writers, influenced by the similarity in sound, have insisted upon identifying Ye-ma-t'ai with the Japanese Province of Yamato, far away to the eastward, in the heart of the mountainous peninsula forming the boundary of the Inland Sea in that direction. It is hard to believe, however, that when the careful and evidently well-informed Chinese historians speak of a maritime region with an extremely mild winter climate, lying far to the south, they really mean an inland Province with a decidedly cold winter, situated in the distant east.

Nevertheless there may exist a connection between Ye-ma-t'ai and Yamato after all. Both the Chinese historians and their own legends represent the primitive Japanese as located first of all in Kyushu, where in fact the word "Yamato" does actually occur, as a place name in both Higo and Chikugo Provinces.[18] We know further that this name has been applied by the Japanese people to themselves in a very definite way; Yamato damashii, for example, means the spirit of the Japanese people, not that of the Province of Yamato. Hence, it seems possible at least that "Yamato" was the name applied to themselves, while still in Kyushu, by the people whom the Chinese usually referred to as the Wo and that when, as we shall see, they transferred their seat of government to central Japan they carried their name with them.

CULTURE AREAS IN THE KOREAN PENINSULA

The Korean peninsula during these times, just prior to and about the beginning of the Christian era, was divided into two quite dis-

[17] H. Maspéro: Bull. École Française d'Extrême Orient, vol. 9, 1909, pp. 593 et seq.; N. Peri, ibid., vol. 10, 1910, p. 715, note 1; C. E. Maitre: La littérature historique du Japon des origines aux Ashikaga, ibid., vol. 10, 1910, pp. 564–596; reference on p. 580, note 1.

[18] Frank Brinkley and Baron Kikuchi: A History of the Japanese People from the Earliest Times to the End of the Meiji Era, New York and London, 1912, p. 84; W. G. Aston (transl.): Nihongi, Chronicles of Japan from the Earliest Times to A. D. 697, Trans. and Proc. of the Japan Soc., Supplement 1, 2 vols., London, 1896, reference in vol. 1, p. 226 and note 8.

tinct culture areas. In the north and extending over into what is now southern Manchuria were various tribes with cultures basically akin to those of eastern Siberia generally, though beginning to be modified by influences both from the neighboring Chinese states and from Central Asia.[19] Farther to the south the peninsula was the home of the peoples called by the early Chinese writers the "Three Han." While the precise boundaries of these are unknown, generally speaking the Ma-Han occupied the west and southwest of the peninsula, with the Shên-Han to the east of them, on the Sea of Japan, and the Pien-Han in the extreme south. These three Han peoples were clearly recognized by their Chinese contemporaries as quite distinct from their northern neighbors, while on the other hand there evidently existed between them and the primitive Japanese an extremely close kinship if not indeed an actual identity. The same was also true, apparently, of the people of Quelpart Island, where traces of southern contacts are unmistakable to this day.[20] This entire region, in fact, formed in prehistoric times a distinct culture area whose closest connections are to be sought in the Chinese coast lands as they were before they came under the influence of Chinese civilization. It was only shortly before the beginning of the Christian era that bands of refugees, fleeing from the wars then devastating China, founded various states in southern Korea in which they introduced that Late Bronze Age culture which then characterized their own country. Shên-Han—later the kingdom of Hsin-lo, or Silla—in spite of its comparative isolation with regard to China, maintained especially close relations with that country, and the consequent superiority in culture which it enjoyed as compared with its immediate neighbors is evident throughout its history.

INTRODUCTION OF BRONZE AND IRON INTO JAPAN

There can be little doubt that it was from these newly founded states of southern Korea that metal was first introduced into Japan. The history of bronze in that country is peculiar. It can not, in

[19] On the old Neolithic culture of eastern Asia, see R. and K. Torii: Études archéologiques et ethnologiques: Populations primitives de la Mongolie Orientale, Journ. College of Sci., Tokyo Imp. Univ., vol. 36, 1913–1915, art. 4; also review of same by H. Maspéro in Bull. École Française d'Extrême Orient, vol. 14, 1914, pp. 79–80.

[20] H. B. Hulbert: The Island of Quelpart, Bull. Amer. Geogr. Soc., vol. 37, 1905, pp. 396–408, passim.

For the probable Japanese affinities of the people of Quelpart, cf. E. H. Parker in Chinese Recorder and Missionary Journ., 1885, p. 303; also W. G. Aston, Nihongi, vol. 2, p. 323, note 5.

A seventh-century king of T'am-na, as the island was then called, bore a name, Yuritoro, which has a decidedly Japanese sound.

fact, be said that a true Bronze Age ever existed there at all.[21] The records of the Later Han dynasty describe the people of Wo, early in the Christian era, as still in the Neolithic stage of culture. This statement regarding their ignorance of metal at that time is strikingly confirmed by the discovery in various parts of western Japan, in association with stone implements, of Chinese coins of the first century of our era.[22] The histories of the Wei and Chin dynasties, on the other hand, referring to the third and fourth centuries, mention iron as known to the Wo. It would appear, therefore, that the very brief and wholly exotic bronze culture which archeological research has disclosed to us in Japan must have fallen somewhere about the second century or so of our era.

Bronze remains in Japan are few and far betweeen, and such as there are occur only in the western portion of the country. They are quite unknown anywhere to the east of the Lake Biwa area, that isthmian region of central Japan where the Ainu held back their Mongoloid foes through so many centuries. Aside from ceremonial objects, the known remains consist mainly of swords, daggers, and arrowheads—all closely resembling well-known Chinese Bronze Age types. The discovery of molds indicates that some casting was done in Japan; but the raw material and a great proportion of the finished articles seem to have been imported, either from Korea or even direct from China, as is also suggested by the name, *Karakane*, which may mean either Korean or Chinese metal. Introduced only after its use in China had already been largely superseded by that of iron, it was but a short time before bronze was overtaken and displaced by the later metal in Japan also. And so effectively was it eclipsed, save of course for ornamental and ritual objects, that neither the Kojiki nor the Nihongi,[23] the two earliest Japanese historical works that have come down to us, betray the slightest recollection of a former Bronze Age; the use of copper arrowheads upon one occasion being mentioned solely as something unusual.

But, if the influence of bronze upon the cultural development of Japan was thus slight, with iron the case was far otherwise. Historical notices are wanting; but good grounds exist for thinking that iron reached Japan merely as one element of an entirely dif-

[21] The British Museum's "Guide to the Antiquities of the Bronze Age," 1904, is hardly exact in stating that the Japanese were already in the Late Bronze Age when they entered the islands; they had long been in Japan when the knowledge of bronze was brought to them. It was a case of a cultural, not a racial, migration.

[22] Dr. K. Hamada, of the Kyoto Imperial University, in personal letters of July 10, 1917, and Dec. 20, 1920.

[23] The Kojiki dates from 712 A. D., the Nihongi from 720. Chamberlain's translation of the former and that of the latter by Aston have already been cited. There is also another of the later work, by Dr. Karl Florenz: Nihongi, "Zeitalter der Götter," Tokyo, 1901.

ferent material culture complex, partly Chinese and partly Central Asiatic in origin,[24] which had taken form somewhere in Korea and which was far higher than anything that the Japanese islands had yet known. That this cultural invasion was the result of actual conquest of any part of the country in a military sense can not be categorically stated; but the presumption seems on the whole in favor of something of the kind.

OTHER EVIDENCES OF INVASION FROM KOREA

The evidence of language, for one thing, appears to point in this direction. Japanese belongs to an independent family, whose only other members are Korean and Loochooan, and such indications as there are point to central rather than to southern Asia as the region of its origin.[25] The most plausible conjecture—in the present state of our knowledge it can be nothing more—would seem to be that it reached Japan as the tongue of a relatively highly civilized body of invaders, not necessarily large, penetrating southward from the Korean peninsula and imposing their authority and their language upon the less civilized tribes, presumably of mixed Ainu and southern Mongoloid origin, whom they found in possession of the western portion of the islands. That such movements were constantly recurring within Korea itself, we know from the Chinese records. About 200 B. C., for example, when refugees from China conquered the state of Chao-hsien, in southern Manchuria, the king of the latter country escaped southward by sea with several thousand of his followers and secured a footing for a season in Ma-Han in the southwest of the peninsula, only eventually to be beaten out again.[26] That a similar raid, or series of raids, during the latter half of the second century of our era or thereabouts, should have been the means of introducing an Early Iron Age culture among the Wo, seems both possible and plausible.

The most conspicuous feature of this period in Japan, next to the use of iron itself, was the practice of dolmen burial. A careful

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[24] Among the traces of central Asiatic influence upon the Early Iron Age civilization of Japan are the reliance upon horse archers as the principal figting arm; the use of the *nari-kabura* or "sounding arrow"; the sacredness attached to certain horses, usually piebald or albino; sword worship; divination by means of a deer's shoulder blade; and the custom of burying living retainers about the tumuli of kings and nobles.

Bashford Dean, in his "Catalogue of the Loan Collection of Japanese Armor," Metropolitan Museum of Art, New York, Handbook No. 14, 1903, p. 28, points out that the earliest metal armor of Japan, about 800 A. D., shows a relationship in many ways to that of central and eastern Russia.

[25] Legge ("Chinese Classics," vol. 5, p. 74) makes the interesting suggestion that a polysyllabic language may have been spoken among the pre-Chinese natives of Shantung. As is well known, Chinese is monosyllabic and tonal.

[26] E. H. Parker: On Race Struggles in Corea, Trans. Asiatic Soc. of Japan, vol. 18, 1890, pp. 157–228; reference on pp. 210 et seq.

study of the available data, both historical and archeological, points to Korea again, and probably to the northern rather than the southern portion of the peninsula, as the source whence was introduced into Japan this custom of burying the illustrious dead in megalithic chambers covered by vast mounds of earth. Dolmens, in general somewhat smaller and simpler in type than those of Japan, occur in Korea in large numbers, particularly in the north. Farther down in the peninsula their place tends to be taken by still simpler stone cists; but these contain horse trappings, stone models of metal swords and arrowpoints, and wheel-made pottery, all closely resembling and in most cases absolutely identical with corresponding remains in dolmen interments in Japan.

It is a matter of historical record, reinforced by archeological evidence, that this type of burial came to an end in Japan about the seventh or eighth century. Regarding the date of its beginning, however, opinions have been widely at variance, although generally speaking it has been placed far too early.

While it is true that bronze and even stone objects have been found in connection with Japanese dolmen interments, that these are mere funerary survivals is shown by the fact that the vast majority of implements are of iron from first to last. The occurrence of horse trappings in these interments is of great significance. The Chinese records are most explicit to the effect that the people of Japan and of southern Korea at the beginning of the Christian era and for at least a century or two after had neither horses nor cattle. Hence, inasmuch as stirrups, bits, and other objects of iron are recorded as occurring throughout the Dolmen Period, it follows that the latter itself can only date back to the epoch of the introduction of iron and the horse, somewhere apparently about the end of the second century.

THE INTRODUCTION OF AGRICULTURE PROPER

To what extent the primitive Japanese in days prior to the advent of metal depended upon planting for their subsistence we do not know; but the Chinese accounts afford evidence of what is otherwise intrinsically probable, that they possessed a hoe culture, carried on in all likelihood largely if not exclusively by the womenfolk. Under such a system, for several reasons, no very great growth of population could ever take place. It was only the introduction of true agriculture, which in southeastern Asia means the growing of irrigated rice, that made possible the vast increase in numbers and consequent economic and military strength essential to the development of a powerful national entity. This great advance in civilization was another element of that distinctive culture com-

plex characterising the Japanese Early Iron Age. That it, too, was derived from Korea is indicated, among other signs, by the entire absence in Japan of the water buffalo, the plow animal par excellence in the irrigated rice culture of China, and the use in its stead of a bullock of identical breed with that of the neighboring peninsula.

Such a revolution in the economic life of a people as that implied by a change from a hoe to a plow culture has naturally its social aspects also. In hoe culture it is almost invariably the women who do the planting, while the men fish and hunt. No one exchanges the excitement and activity incident to the career of a hunter or a deep-sea fisherman for the monotonous drudgery that falls to the plowman's lot save under strong compulsion of some sort. In other words, the bringing about of such a change almost necessarily implies the relationship of master and serf. That such a system obtained in the Japan of the Early Iron Age, we have abundant evidence.[27] This fact affords additional presumption of conquest of some sort, whether from without or from within.

HISTORICAL EVIDENCE FROM CHINESE RECORDS

For such historical evidence as exists regarding this phase of Japan's cultural development we are still forced to rely almost wholly on the Chinese records. Writing seems to have been applied in Korea to the keeping of annals only toward the close of the fourth century of our era, and in Japan somewhat later still, so that what is told regarding earlier periods must rest solely upon oral tradition and legend.[28]

The histories of the Later Han and the Wei dynasties of China inform us that for a period of 70 or 80 years, ending about the close of the second century, the people of western Japan—from what cause, is not stated—were in great turmoil, the disturbances ending only with the rise of a powerful queen (almost certainly the "empress" Jingô Kôgô of Japanese legend) who by her command of magic extended her authority far and wide over the various tribes of the Wo.[29] She had, the accounts go on to say, no husband, but was assisted in governing by her brother—apparently an only partly

[27] On this see, e. g., Hara, op. cit., pp. 80 et seq.

[28] Maurice Courant, Stèle chinoise du royaume de Ko Kou Rye, Journ. Asiatique, Ser. 9, vol. 11, 1898, pp. 210–238, states (pp. 223 et seq.) that writing became habitually used in western Korea in the last quarter of the fourth century. W. G. Aston, Trans. Asiatic Soc. of Japan, vol. 16, 1888, p. 46, thinks Chinese writing (there is of course no question of any other) was diffused in the various Korean kingdoms in the last half of the same century. C. E. Maitre, op. cit., p. 584, says writing was definitely introduced into Japan from Korea at the beginning of the fifth century.

[29] See Murdoch, op. cit., vol. 1, pp. 36 et seq.

understood instance of royal brother-and-sister marriage, a custom which we know formerly existed in Korea also.[30]

That a marked change of some kind, whether as the result of actual invasion or not, really did take place at this time is further shown by the fact that the Chinese records of the period sometimes refer to "Great Wo" by the alternative name of "the Queen Country," although declaring specifically that in earlier times it had been ruled over by kings. It seems to have been the case that these female rulers of the Wo derived their powers from a belief that they in some special sense—most likely through actual physical descent—represented the Sun Goddess, whose oracles and priestesses they were.

It was about this same period, apparently, that there arose on the main island, in what was later the province of Izumo, an independent kingdom which had especially close relations with the country of Hsin-lo, or Silla, facing it across the Sea of Japan.[31] It is perhaps in this Izumo region that is to be sought the land of Ko-nu, mentioned by contemporary Chinese writers as situated across the sea from Ye-ma-t'ai (in Kyushu, as we have seen), and more to the eastward. The people of Ko-nu, we are further told, although of the same race as the Wo, were generally on terms of hostility with the latter, and unlike them were ruled over by a king, who was in diplomatic correspondence with the Chinese representatives in Korea.

Thus it seems clear that beginning about the latter half of the second century western Japan was invaded from Korea by a decidedly high culture characterized by the use of iron, the manufacture of wheel-made pottery, the possession of domestic animals, the custom of fighting on horseback, the practice of true agriculture, and the burial of the illustrious dead in dolmens covered by huge mounds of earth. It is possible that the bow played a part in the extension of this culture, for the original Mongoloid settlers of western Japan, like their kinsmen of the Chinese littoral and so many of the modern peoples of Indo-China and Indonesia, appear to have been spearmen rather than archers.

Of the substitution of male rule for female rule among the Wo there is no historical record. But that it took place not long after the time of the great queen just mentioned and that it was due to the growing influence of Chinese ideas may be held as certain. The former divine queens seem to have survived merely as chief priestesses of the Sun cult, while the actual power was henceforth vested in the male heads of the ruling clan, the historical mikados,

[30] Hulbert, op. cit., p. 81.

[31] On the contact between Hsin-lo and the Izumo region of Japan, see Aston, Nihongi, vol. 1, p. 166 and note; W. E. Griffis: Corea, the Hermit Nation, New York, 1882; reference in Preface, p. v; Baelz, op. cit., p. 525.

also, of course, descendants of the Sun Goddess and therefore god-kings in their own persons.

It was during this same period of her Early Iron Age that Japan received, through Korea but eventually from China, two fresh cultural acquisitions, whose importance it would be difficult to exaggerate. These were the Buddhist faith and the art of writing. The story of the way in which these additional factors in the national life came to be introduced can not be gone into here. But it will readily be seen how very great must have been their influence as unifying and civilizing agents among a congeries of tribes dwelling upon a relatively low culture plane and ruled over by a turbulent, disunited, and illiterate aristocracy which had as yet learned to pay but small respect to the authority of the central government.

EXTENSION OF JAPANESE OCCUPATION OF THE MAIN ISLAND

The fact that bronze implements have been found only to the westward of the Lake Biwa region would suggest that the Mongoloid advance at the expense of the Ainu got no farther than that point until after the introduction of iron. It is possible, however, that even during the Neolithic period independent bands of the invaders may have cruised in canoes farther eastward, planting settlements along the coast but leaving the central mountain ranges in the hands of the aboriginal population. We know that it was by this method of coastwise advance in large fleets of war boats that the Japanese effected the conquest of much of the northern part of the main island in the full light of the historical period, during the seventh and eighth centuries, and it must have been by a similar process that they acquired a lodgment in the islands in the first place.[32] At all events, there is some evidence, slight though it be and mainly of a legendary character, that the coastal plains as far east as Tokyo Bay were already occupied by settlements of peoples akin to but independent of the Yamato when the latter established their supremacy there. The Yamato-dake story, for example, pure myth though it be in the main,[33] suggests this; for in it that hero appears as warring against peoples kindred to his own until he passes the mouth of Tokyo Bay (traveling by sea, be it noted); it is only beyond that point that he is represented as coming in contact with the Ainu.

It seems certain, at any rate, that the efforts of the Yamato to extend their authority over eastern Japan began very soon after their occupation of the Lake Biwa region. For the Japanese annals, just now beginning to have some slight historical value, mention a defeat

[32] Regarding these boat expeditions, see Aston, Nihongi, vol. 2, pp. 252 and 263; also, Hara, op. cit., p. 110.

[33] For the Yamato-dake myth see Aston, Nihongi, vol. 1, pp. 200 et seq., B. H. Chamberlain, Ko-ji-ki, pp. 201 and 205 et seq.

inflicted at the end of the fourth century upon one of their war parties by the Ainu of the rugged peninsular region between Tokyo Bay and the Pacific Ocean. And 80 years or so later—in the year 478 A. D., to be exact— the Chinese records inform us that the emperor then reigning, Shun Ti, of the Early Sung Dynasty, received a letter[34] from the ruler of the Yamato, stating that his father had conquered toward the east 55 states of the Maojên, or "hairy men" (the Ainu, of course), and on the west 65 states of the I-jên, or "barbarians." Who these latter were is uncertain, but they were perhaps most likely fragments of the pre-Yamato population of western Japan, of mixed Ainu and Mongoloid descent, which, dwelling in mountainous areas or outlying islands, had managed hitherto to escape conquest by the Yamato. Southern Kyushu in particular we know long remained independent and hostile. The almost entire absence of dolmens here indicates the slight control exercised by the Yamato over this region during their Early Iron Age, and this inference is most abundantly confirmed by their own records.

LOSS OF CONTINENTAL TERRITORY

But, though the influence of the mikados was being strengthened during this period in Japan proper, as much can not be said with regard to their relations with the continent. During much of the Early Iron Age western Japan and particularly northern Kyushu seem to have been far less closely allied in feeling to the Yamato region than they were to southern Korea. At times this consciousness of kinship actually took the form of alliances between the peoples on the two sides of the Strait of Tsushima for waging war—"rebellion" in the official Japanese phraseology—against the divine Yamato rulers of central Japan. It was only by great efforts that the latter were able to maintain even the loosest control over their kinsfolk of the lower end of the peninsula.[35] Geography, in the shape of the hundred miles of sea between Japan and Korea, was working as inexorably against them as did the English Channel against the retention of Normandy by the English kings—in many ways a closely parallel case.

Finally, in the latter half of the seventh century the age-long friendship between the kingdom of Hsin-lo, the ancient Shên-Han, and China, then under the sway of the powerful T'ang Dynasty,

[34] Thus showing that the Japanese were now beginning to conduct their diplomatic correspondence in writing, if indeed they had not already been doing so for a century or two; but the art remained for long a secret confined to certain hereditary guilds of Chinese or Korean extraction, whose members thus acquired vast influence with the rulers and great nobles of the Yamato whom they served as scribes.

[35] On the dominance of Japan in Korea during the early centuries of the Christian era, see Kanichi Asakawa: The Early Institutional Life of Japan. Tokyo, 1903, pp. 80 et seq.

culminated in a joint attack upon the Yamato by sea and land, which resulted in their total expulsion from the peninsula. The people of Quelpart, of Japanese or closely kindred stock, kept up for several centuries a quasi-independent existence as the kingdom of T'am-na but eventually gravitated toward Korea, geographical propinquity proving stronger than the ties of race and culture.

At the time, no doubt, this loss of the continental portion of their territory must have seemed a catastrophe of the direst sort. In the long run, however, it proved of incalculable benefit.[36] For while receiving just as formerly the culture stimuli emanating from the continent, the Yamato no longer had to dissipate their energies in efforts to retain hold of regions on the mainland which were steadily growing farther apart from them in feeling and culture. Thus, able to give their undivided attention to their home problems, they set to work in earnest to obliterate the last remaining frontiers within the Japanese islands themselves.

FURTHER CONSOLIDATION OF THE INSULAR DOMAIN

The independent communities still surviving in the west, of which those mentioned as existing in southern Kyushu were the chief, were absorbed in short order. The last rising of the old independent stock of southern Kyushu took place at the end of the seventh century, barely a generation after the expulsion of the Yamato from their last foothold on the continent. But the separatist tendencies of the region, fostered by its geographical configuration, have been manifest throughout its history, the last instance being that of the famous "Satsuma rebellion" of 1877.

The subjugation of the still unconquered Ainu of the north and east presented a far more serious task. The mass of the people of western Japan, hardly touched by the new cultural influences from the continent, save in so far as these facilitated their exploitation by their rulers, had long since sunk to the status of abject predial serfdom and had lost such military virtues as they may once have possessed. The aristocracy, we know, were splendid warriors, gorgeously equipped and accustomed to fighting on horseback with longbow and sword. When called out en masse they no doubt proved a most effective if somewhat undisciplined militia. But aside from the personal guards of the rulers and great nobles, recruited largely from the Ainu and the pre-Yamato populations of southern Kyushu, there was no standing army and consequently no force ready at all times to take the field on short notice against the sudden incursions of the unconquered aborigines. These fierce

[36] Hara, op. cit., pp. 122 et seq.

fighters were by no means content merely to act on the defensive. Throughout their history as an independent people they evinced an entire willingness to meet their enemies quite halfway. Their usual method of waging war was to strike the settlements of the foe unawares and then be off again with their booty and captives, leaving behind them a trail marked in blood and fire, before troops could be brought up against them. The attitude of the bulk of the Japanese peasantry toward these savage raiders is vividly reflected in a very ancient song, attributed to the mythical hero Jimmu, which says that one Emishi (i. e., Ainu) is a match for a hundred men.

THE AINU FRONTIER

It was clearly for strategic reasons that the Yamato had moved their seat of government in the first place from Kyushu to the frontier region about Lake Biwa. For it was there that Ainu incursions were most to be dreaded and there, too, that they could be most easily repelled before they had penetrated far into the country. That such a radical change of base should have been made, in spite of the very great importance which we know the Yamato rulers attached to the maintenance of their hold on southern Korea, gives us a measure of the anxiety with which they regarded the "Ainu question." Only a motive of the utmost cogency could have induced them to remove so far from the position close to the Strait of Tsushima which they had hitherto occupied.

The settlement of the Ainu problem was at length effected; but it was only by dint of the hardest fighting, protracted through centuries. The possession of iron weapons and of a force of mounted archers accustomed to maneuver at a gallop over rough ground must have given the Yamato a great advantage over the Ainu in the open field. But as the latter were slowly pushed back northeastward they absorbed more and more of the civilization of their enemies with a consequent increase in their own powers of resistance, while the Yamato armies, on the other hand, advancing both by land and by sea, met with ever greater difficulty in getting up their supplies from the cultivated districts far in their rear. Moreover, it was not enough merely to occupy the lowlands near the coast with blockhouses and military colonies. The central mountain ranges had also to be invaded and their inhabitants dispossessed or subdued, if there was to be any security for the always lengthening lines of communication. In view of the overwhelming difficulties attending the task, it is no wonder that it was so long of accomplishment; while the dogged stubbornness with which the centuries-long

battle was waged on both sides says a vast deal for the fighting qualities of Ainu and Yamato alike.

For some reason progress was much more rapid on the west than on the east coast, so that about the close of the seventh century the Yamato had after a fashion occupied the territory along the Sea of Japan nearly up to the thirty-ninth parallel. On the Pacific side the Ainu were then holding out along a line roughly corresponding to latitude 37° N. The next few campaigns pushed the frontier back, on the west, as far as a spot a trifle south of latitude 40° N., where the Akita fort was built. From this point the boundary extended in a general southeasterly direction across the central mountain ranges to the Pacific, reaching the coast about in latitude 38° 40′ N., some 50 miles or so north of the Taga fort, whose overgrown earthworks still stand, not far from the present city of Sendai.[37]

At this point, in the latter half of the eighth century, the still unconquered Ainu made a desperate effort to regain their lost ground. They took the Taga fort, massacred its commander and garrison, and pushed far down the eastern coastal plain toward that Tokyo Bay region from which their ancestors had been driven something like 300 years before.

But the Yamato government, albeit with difficulty, kept large forces in the field year after year, while the aborigines, barbarians as they were, aided in their own subjugation by indulging in suicidal wars among themselves. It was fortunate for them that the Yamato, before the loss of their continental possessions left them free to attend to their internal problems, had adopted the peaceful and humane creed of Buddhism with its aversion to bloodshed. For, in obedience to the behests of their faith, they carried on no mere war of extermination but made a genuine effort to civilize and assimilate the conquered natives and to place them on the same footing with the other subjects of the Mikado. At first prisoners of war were distributed in the western part of the islands in small bodies and were given rations until they should learn to become self-supporting; while later on the policy was adopted of organizing them into villages on the same basis as the rural population elsewhere. Thousands of them, first-class fighting men as they were, accepted enrollment in the Japanese armies for service against their still unsubdued kinsmen. Offices and gifts were bestowed on surrendered chieftains, while missionaries, in some cases themselves converted Ainu who had taken holy orders, made every effort to win the aborigines to the Buddhist faith.

[37] On the successive old Yamato-Ainu frontiers, see Hara, op. cit., pp. 67 et seq., 86 et seq., 104, 119, 147 et seq.; N. G. Munro, Primitive Culture in Japan, Trans. Asiatic Soc. of Japan, vol. 34, Part II, 1906, pp. 1–198; reference on p. 166; *idem*, Prehistoric Japan, p. 597.

FINAL CONQUEST OF THE AINU

Finally by the close of the tenth century the subjugation of the Ainu of the main island could be regarded as accomplished. But it was long before they were completely assimilated. They rose again and again, even as late as 1332, while a few villages of them were still to be found about the shores of Aomori Bay so recently as the eighteenth century.

That portion of the race living in Yezo, Sakhalin, and the Kuriles retained its independence for some time longer. The last serious effort of the Yezo Ainu to expel the Japanese occurred in the latter part of the seventeenth century, when with their primitive weapons they made a brave but hopeless fight against their foes clad in iron armor and equipped with matchlock guns and keen steel swords.

As a distinct people the Ainu have almost wholly disappeared, with the exception of the few thousands still living in the island of Yezo. Nevertheless they form a very large element in the racial composition of the Japanese nation to this day.[38]

As usual in cases where crossing has occurred between Mongoloid and other races, the external physical characteristics of the former have tended to be dominant, although apparently the same does not hold to quite the same extent regarding skeletal traits. Traces of Ainu mixture are visible throughout the country, from the Loochoos and Satsuma in the far south to Yezo on the north, while in isolated regions like the mountain fastnesses of Kozuke, Shinano, and Echigo Provinces in the center of the main island, there still occur surprising numbers of pure Ainu types. Particularly strong was this strain among the former Samurai, or knightly class, in large part descended from the Ainu incorporated in the Japanese armies of the eighth and ninth centuries.[39] To this inheritance it was that the haughty two-sworded man of later times owed his less Mongoloid features, ruddier complexion, and heavier beard, to say nothing of his splendid fighting qualities.

It would be difficult to exaggerate the influence which the Ainu have exerted over the historical development of the Japanese Empire. For to the long centuries of warfare which their subjugation entailed were due the rise of that hereditary warrior class and that system of military government, without which Japan would almost

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[38] On the large Ainu part in the modern Japanese racial complex, see Kanichi Asakawa: The Origin of the Feudal Land Tenure in Japan, Amer. Hist. Rev., vol. 20, 1914–15, pp. 1–23; reference on p. 17; Matsumoto, op. cit., pp. 73, 75 et seq.; David MacRitchie: The Ainos, Internationales Archiv für Ethnographie, vol. 4, Supplement, 1892, passim; Romyn Hitchcock, op. cit., p. 450.

N. G. Munro (Prehistoric Japan, p. 634) says the religion of the Yamato was much more deeply influenced by the Ainu than is generally supposed.

[39] Asakawa, Origin of Feudal Land Tenure, p. 17; Matsumoto, op. cit., pp. 75 et seq.

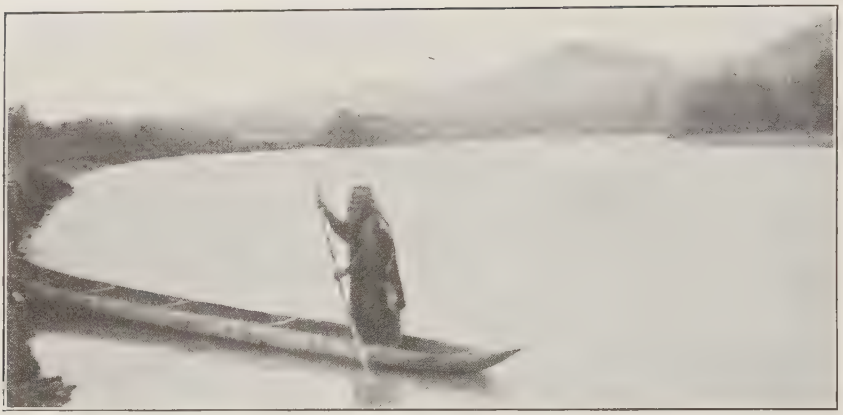
certainly have vegetated into a second Korea—in other words, a feeble imitation of China, without either the will or the force to think and act for herself. It is pleasant to be able to state, from personal observation, that the Japanese authorities are doing all that they can to elevate and educate the remnant of the Ainu, and assist them to a point where they can take their proper place as civilized men and women in the world of the twentieth century.

CONCLUSION

The physical and cultural traits which we regard as peculiarly Japanese may, then, be traced to three separate and distinct geographical areas.[40] Basically, both in race and in the fundamentals of their culture, the Japanese are most closely akin to the ancient inhabitants of the Asiatic coast lands during the Neolithic period. Superimposed upon this foundation and affecting mainly the ruling classes, was that higher type of civilization which began to reach Japan about the beginning of our era, and which was accompanied by a certain infusion of fresh blood, largely from Korea but also to a not inconsiderable extent direct from China. Finally, to the long contact with the ancient aborigines were due the addition of a most valuable element in the racial complex and the acquisition of that fighting spirit, with its traditions of unflinching loyalty and self-sacrifice, that has been so largely responsible for the rise of Japan as a modern power.

[40] H. J. Fleure (Geographical Factors, Helps for Students Series, No. 44, London, 1921) makes the interesting suggestion that it may be the imperfect accord of widely separated inheritances in the same individual that has given the Japanese the sensitiveness to climatic differences which has hitherto stood in the way of their succeeding as colonists in Formosa or Sakhalin.

AINU MAN AND WOMEN AT PIRATORI, ISLAND OF YEZO; THE MAN HAS CEREMONIAL HEADDRESS AND MUSTACHE LIFTER. THE DESIGNS ON THE CLOTHING ARE DISTINCTIVE OF THIS RACE



1. OLD AINU MAN OPERATING CANOE FERRY IN INTERIOR OF ISLAND OF YEZO. THE AINU, IN COMMON WITH OTHER NORTH PACIFIC PEOPLES BOTH OF ASIA AND OF AMERICA, WERE EXPERT CANOEMEN

2. KOREAN BULLFIGHT. THESE FIGHTS, ORIGINALLY OF RITUAL SIGNIFICANCE, SEEM TO HAVE FORMED AN ELEMENT OF THE IRRIGATED RICE CULTURE COMPLEX, IN ASSOCIATION WITH WHICH THEY ARE FOUND FROM JAPAN TO MADAGASCAR

TYPE OF JAPANESE FISHING WITH AID OF LARGE DIP NET, INTRODUCED FROM SOUTHERN AND CENTRAL CHINA

1

1. AINU VILLAGE. NOTE PILES OF FIREWOOD PROVIDED AGAINST THE BITTERLY COLD WINTER. THE AINU FORMERLY USED EARTH-COVERED DUGOUTS AS COLD-WEATHER RESIDENCES, WHILE THEIR STOREHOUSES ELEVATED ON PILES POINT TO CONTACT WITH SOUTHERN INSULAR PEOPLES

2

2. TYPE OF PRIMITIVE JAPANESE HUT SURVIVING AMONG MODERN PEASANTRY. PHOTOGRAPH BY COURTESY OF THE FREER GALLERY OF ART

1

1. FAMOUS SHRINE OF THE SUN GODDESS AT ISE, IN WHICH IS PRESERVED THE PRIMITIVE JAPANESE TYPE OF HUT, ALLIED TO SOUTHERN INSULAR FORMS, VERY DISTINCT FROM THE CHINESE STYLE OF ARCHITECTURE IMPORTED IN HISTORIC TIMES. PHOTOGRAPH BY COURTESY OF THE FREER GALLERY OF ART

2

2. VIEW OF NARA, ONE OF THE CAPITALS OF JAPAN IN THE EIGHTH CENTURY, SHOWING ARCHITECTURE OF CHINESE BUDDHIST ORIGIN

1. JAPANESE PEASANTS DIGGING EDIBLE BAMBOO SHOOTS. THE HAT, RAINCOAT, SPADE, HOE, AND STYLE OF CLOTHING ARE ALL TRACEABLE TO THE SOUTHERN CHINESE LITTORAL

2. JAPANESE RICE CULTURE, INTRODUCED FROM SOUTH AND CENTRAL CHINA, PERHAPS BY WAY OF KOREA. WOMEN IN JAPAN STILL PERFORM A LARGE PART OF THE FIELD WORK, JUST AS IN PRIMITIVE TIMES

Photograph by courtesy of the Freer Gallery of Art

1. Typical Japanese Torrent Bed in Winter. Owing to the Almost Total Lack of Navigable Rivers, the Original Japanese Conquest Was Largely Confined at First to Seaboard Plains Accessible to Their Fleets of War Boats

2. Lake Hakone, in Central Japan, Where the Original Ainu Long Held Back the Japanese Invaders Until Outflanked by Sea, as Happened Again and Again, Until the Process of Conquest Had Been Completed

1. WINTER SCENE IN THE NIKKO RANGE, PART OF THE CENTRAL BACKBONE OF JAPAN, IN WHOSE FASTNESSES AINU TYPES STILL SOMETIMES OCCUR IN GREAT PURITY

2. LOOKING NORTH FROM THE SCARP OF THE ANCIENT JAPANESE HILL FORT OF TAGA TOWARD THE HILLS STILL HELD BY THE ABORIGINAL AINU IN THE EIGHTH CENTURY

INSCRIBED STONE OF THE EIGHTH CENTURY AT THE TAGA FORT, NEAR THE ANCIENT AINU-JAPANESE FRONTIER, A FEW MILES NORTH OF THE MODERN CITY OF SENDAI

THE EXCAVATIONS OF THE SANCTUARY OF TANIT AT CARTHAGE[1]

By Byron Khun de Prorok

Codirector of the Carthaginian excavations.

[With 4 plates]

The Sanctuary or Temple of Tanit is the first Punic ruin to be found "in situ" in Carthage. Father Delattre has uncovered many Punic tombs at Carthage, but the richly crowded area "of the Temple of Tanit," now being exhumed, is the first trace of Carthaginian remains of the Phœnician period in the original position. The discovery was made by two amateur archeologists of Tunis, Mr. Icard and Mr. Geilly, and the discovery was at once communicated to the Académie des Inscriptions et Belles Lettres by J. B. Chabot, membre de L'Institut, and expert in the Phœnician Languages.

The ruin was found in one of the most common ways in oriental countries—that is, by tracing the selling of antiquities by the local Arabs. A beautiful Punic inscription was being sold when Mr. Geilly asked whence it came. He was told by the Arab that he had found it in the mountains above Carthage, and for two weeks a search was made in the indicated place. These indications were a ruse so that the Arab could go on peacefully digging up the antiquities in secret and selling them at once to tourists and collectors. One night the Arab was followed and was seen by the light of the moon to be digging on his hands and knees in a hole. He was caught red-handed, with 10 votive inscription stones near by, and the famous Sanctuary of Tanit was at last located. From the historian Polybius we know that the Temple of Tanit and of Baal Hammon stood in the vicinity of the ancient forum not far distant from the ancient ports. The site of this recent discovery corresponds with the ancient historian's position of the temple, and strangely enough this discovery is situated on the spot called "Salammbô," about 100 yards from where the ancient ports are supposed to have stood. Gustave Flaubert, who wrote the greatest historical novel ever produced in France, would have been pleased if he had lived to know that the temple he had so vividly described

[1] Reprinted by permission from Art and Archeology, Vol. XIX, No. 1, January, 1925.

was being brought back to the civilized world. In digging up this temple this winter, we had constantly in our minds the vivid description of the temple that makes one of the most wonderful episodes of Flaubert's "Salammbô."

The excavation was started by the "Services des Antiquités," and this year we were able to procure the site after many months of deliberation and difficulties on the part of the owners of the coveted piece of land.

The sanctuary is remarkable in being composed of four distinct levels, floors of votive altars, inscriptions, and vases of many new forms.

Each level corresponds with a different period of Carthaginian history. The sanctuary dates from the foundation of Carthage, which is lost in the night of time, but it is only in the termination of the present excavations that perhaps some clue to the real date of the foundation of Carthage may be found. Most historians place the legendary foundation of Carthage by Dido at about 850 B. C. With the termination of the present excavation we hope not only to solve the mystery of ancient Carthage, but also to solve the problems of the great Egyptian influence we have found there, of the practice of human sacrifice, and many other historic questions. The sanctuary existed until the destruction of Carthage by Scipio 146 years B. C. From it we are learning new indications of the religions and customs of a lost empire. The site of the city of Hannibal and Hamilcar has long been a mystery, but the tombs discovered by Father Delattre have shed certain light on the great people who once challenged Rome for the mastery of the ancient world. But nearly everything is yet to be achieved in Carthage, as regards the scientific exploration of the vast antique metropolis of Africa, that once had a population of a million inhabitants and whose area is said to have been 24 square miles.

The Temple of Tanit is our first clue to the Phœnician city that disappeared from the face of the earth during the dreadful conflagration when the city burned for 17 days and the smouldering ruins were plowed through by the revengeful Romans. The excavation is producing thousands of beautifully painted urns, containing rare and precious amulets and other treasures, and elegantly sculptured inscriptions of the days of Hannibal, and hundreds of strange votive altars unknown as yet to archeology. Each time that this great cemetery was filled with offerings it was covered over with a layer of protecting clay and refilled.

HUMAN SACRIFICES AT CARTHAGE

It is hoped that the completion of the excavation of the "area" of the Temple of Tanit may lead to the discovery this coming season

of the plan of the temple itself. One of the greatest problems of this discovery is the solving of the historic question of the human sacrifices of the Carthaginians. The excavation has already yielded thousands of urns filled with the ashes and bones of newly born children and small animals. It is thought that the animal bones were those of animals substituted secretly by parents for their children. The relics have been examined by the Pasteur Institute and found to be largely those of infants.

In six weeks we dug out hundreds of vases, sometimes averaging 50 a day. Nearly all the vases contained ashes of children and we are driven to the conclusion that on this site there were very dreadful holocausts in antiquity.

Diodorus Siculus mentions that in the year 311 B. C. as many as 300 people were sacrificed during one ceremony. The Carthaginians were abhorred by the ancients because of this terrible custom of "passing their people through fire" as in biblical days. One of the most remarkable conditions of a peace treaty ever recorded was that made by Gelon of Syracuse on behalf of the Greeks. After defeating 300,000 Carthaginians at the great battle of Himera, they demanded one single condition, and that was the abolition of the sacrifice of children at Carthage. Darius, King of the Persians, sent an ambassador all the way to Carthage demanding the abolition of human sacrifices and also the eating of little dogs, a great Phœnician delicacy which was considered an abomination in those days.

The awful cult of Moloch continued in the reign of Tiberius, according to the great apologist Tertullian. This Emperor had the priests who performed these "abominations of the Sidonians" crucified in the Temple Gardens where they had performed these ritual sacrifices.

Saint Augustine also spoke of these cruelties, which he said continued even in his day, the sacrifices being made then to Saturn instead of to Baal Ammon. This is a dreadful period of human degeneracy that we are now unearthing in the famous Temple of Tanit, but such is archeology! In one spot we may be uncovering works of priceless art and traces of the advancement of civilization, and in another spot the contrasting decadence shown in the revelation of such a cult as found at Aphrodisium and at Carthage in Africa.

THE URNS DISCOVERED IN THIS YEAR'S CAMPAIGN

(The excavations of floor A)

The first ruin to be located in the excavation was what seemed to be the Roman Temple of Saturn built above the Punic ruin below. We give it this name from a votive inscription found among the

débris of ruined walls. This inscription bore the name of Baal Saturn. Beneath these walls was found the first layer of Punic objects. The Roman conquerors had built right onto the field of votive offerings and other archeological treasures, but had disturbed as little as possible the religious "area." It must be remembered that Rome rebuilt Carthage about 100 years after its destruction and it became in a short time the second city of the Roman Empre.

Floor A is at a depth of about 5½ to 6 meters. The excavation is extremely difficult at the greatest depth because of the continuous infiltration of sea water. This floor contains vases of very delicate workmanship of graceful tulip form. Therein were contained finely worked amulets of the Egyptian deities mingled with the bones and ashes of children from new-born infants to the age of 12 years.

Below this floor we discovered a very important silex of the Neolithic age, a significant find, proving that prehistoric man had also made the peninsular of Carthage his abode. This adds a new field of research in the already well-stocked one of Carthaginian archeology.

Floor A contains many rough stones placed in the form of small megalithic menhirs, and one wonders if a link with the mystery of the dolmens may also be solved by this excavation. North Africa is a rich field of megalithic remains, certainly one of the richest known, for in the plateau region of the Tell in Central Tunisia, I have visited 40 megalithic sites. At Roknia there are 1,400 dolmens to be seen on one site alone. Our new museum at Carthage was fortunate in procuring this year a complete collection of objects from the Dolmens of Dougga, affording splendid documentation on this engrossing subject.

The vases found in floor A contained veritable treasures of jewelry, gold leaves, ivory masks, gold ornaments, necklaces and bracelets, objects of rare and varied forms, amulets, with the head of jackals, the "Eye of Osiris," the Egyptian god Bes, and the terrible sinister god of the Carthaginians, Moloch.

Floors B and C show also monuments of great Egyptian influence. The altars are obelisk in form and the urns again show amulets composed of the Egyptian Pantheon. However, floor B is not so rich in variety as floors A and C but an extensive study is needed here in cataloging the variety of monuments and the transition of style.

The next floor (C) is as important as the deepest strata, for we meet for the first time the beautiful Punic inscriptions and several scores of new varieties of sculptured votive altars and a wide range of Phœnician pottery.

THE INSCRIPTIONS

The excavation of this floor is perhaps one of the most important of North African archeological researches, for these inscriptions are clues to the epigraphy of a lost empire, to new artistic designs, to new religious customs, and to the new names of Carthaginians of Hannibal and Hanno's days.

We dug up several beautiful stelæ in a very fine grain of stone and the designs were of great variety and workmanship. Temple columns, the tree of life, lotus flowers, Carthaginian priests, the sacred plates, uplifted palms, dolphins, and other mystic symbols, have rewarded the excavators' efforts. One of the most interesting discoveries was made at the base of a great wall. While supervising the digging from floor C, one of the students of the British school at Rome, who collaborated with us in this work, came running from that section of the excavations selected for his minute supervision, to report the finding of a beautifully sculptured stele. In a few moments willing hands had dug away the soil and reached an entirely new type of Punic stele showing a priest with uplifted hands finely sculptured at its face. The Abbé Chabot at once took a squeeze, an important action that is taken the moment a new inscription is located. (The archeologists and students were all supplied with squeezers to be able to take an impression at a moment's notice.) The Abbé Chabot at once announced a new form of Punic epigraphy. It was a maledictory curse of Baal Ammon—"Whoever overthrows this stone shall be shattered by Baal" * * * it commenced.

A few minutes later another inscription appeared with a malediction of Tanit "at the violators of the sacred silence of the area of the Temple of Tanit." A fine Punic inscription placed in the new museum for safety's sake, bears a genealogy of 15 generations, or approximately 500 years of a Carthaginian family whose origin goes back to the Phœnician founding of this Tyrian colony. This field of stelæ has only been "tapped," and it is impossible to calculate the amount of information we may derive from this excavation in regard to the history of Carthage.

The inscriptions of Carthage differ slightly from those of ancient Phœnicia and they are important additions to the epigraphy which forms the first known alphabet of man. There is certainly a great field of scientific knowledge to be published for the benefit of the history of the ancient metropolis of North Africa, and from this ancient sanctuary, near which laps the sea of the ancients, some of the mystery that still surrounds the site of Carthage may in the near future be penetrated.

VOTIVE ALTARS

The votive altars need especial and separate study of their own. The forms and designs are so numerous that nearly every day we find new specimens of Punic design and unknown examples. It would make an interesting study to compare the different specimens of these great altars with those of other antique lands to see if any likeness can be detected.

The altars stand in the temple area in very close formation, under which we found the sacred urns. They were actually covered with painted stucco, and we have found several absolutely intact with the colors still showing after nearly 27 centuries. They range from 1 to 5 feet in height and are composed of a sand stone found at Cape Bon. Many are in the form of the "betel" stone. This is the most common form found. And then comes in greatest number the figure of a mummy standing between columns; then the triangle of Tanit, the lozenge, the disk, the crescent, and replicas of temples, with steps, are also quite common. Near these altars hundreds of Punic lamps were found showing that many of the ceremonies must have been performed at night. Babies' milk bottles, Punic coins, quantities of grim ashes, and pottery of great variety are found around the altars, as well as strange symbols of little-known gods.

The excavation of this historic spot this year was under the direction of Abbé Chabot, membre de L'Institut, and the greatest living expert on the Punic inscriptions, and de Prorok, who purchased the site with a donation given by Mr. and Mrs. Nicholas Brady, of New York. Maj. F. Shorey, of McGill University, Mr. A. Duff, of Oxford University, and Mr. D. Harden, of the University of Cambridge, Rey de Vilette, of the Ecole des Sciences Politiques, Paris, and Horton O'Neill, of St. Louis, Mo., who took the photographs illustrating this article, made up the composition of the staff. M. Poinssot, the learned director of the Service des Antiquités also supervised the work periodically. All these factors insured the careful and proper scientific excavation and documentation of this, the most important ruin discovered in North Africa in recent years. It has turned out to be a veritable treasure mine of antiquity, and a wonderful trace of the empire that once nearly conquered the ancient world.

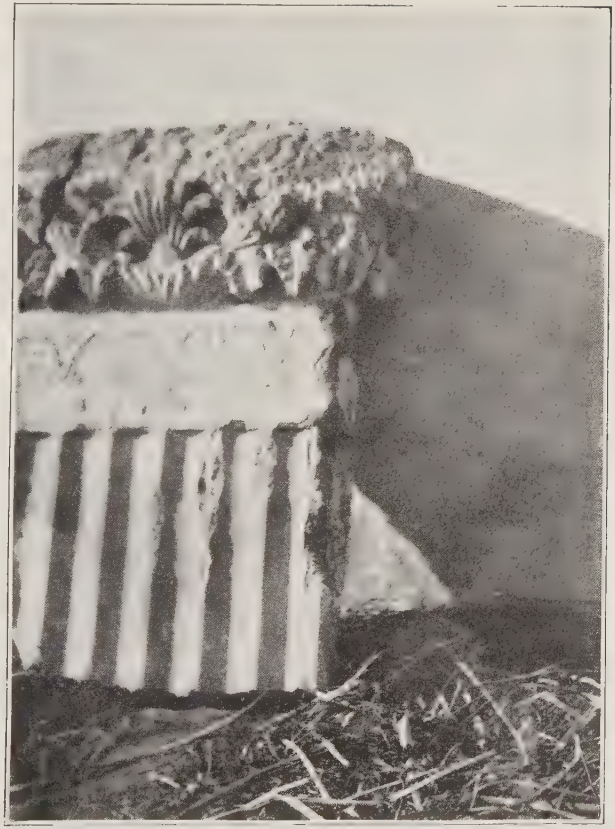
GENERAL VIEW OF THE EXCAVATION OF THE TEMPLE OF TANIT

1. LEFT TO RIGHT: MADAME RENAULT, PÈRE CHALLES, MR. ICARD (DISCOVERER OF TANIT), MR. SANVAGEN, MAYOR OF CARTHAGE, PÈRE DELATTRE, CORRESPONDENT DE L'INSTITUT, ABBÉ CHABOT, MEMBRE DE L'INSTITUT, MR. GROSELLE, DIRECTOR OF THE NEW MUSEUM, PÈRE HUGENOT, PREHISTORIC CURATOR, COUNTESS DE PROROK, MR. COOKINGHAM, U. S. CONSUL, TUNIS, MR. POINSSOT, DIRECTOR SERVICES DES ANTIQUITIES, BARON D'ERLANGER, AND COUNT DE PROROK

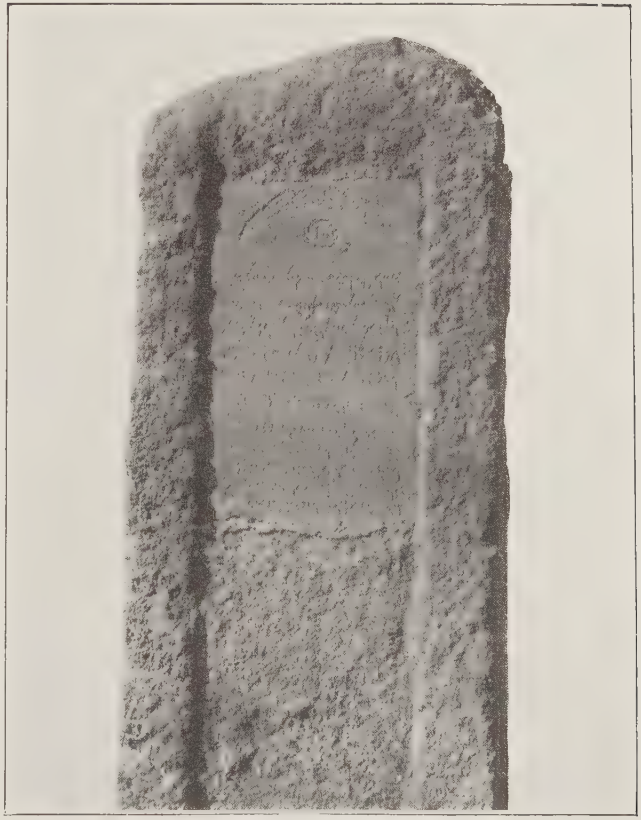
2. BEAUTIFUL AND UNIQUE VOTIVE ALTARS RECOVERED FROM THE SANCTUARY. SEVERAL WERE STILL COVERED WITH THE ANCIENT STUCCO AND STILL PRESERVE VIVID COLORINGS. FIVE URNS WERE FOUND UNDER EACH ALTAR

1. EXAMPLES OF VASES FOUND IN THE TEMPLE OF TANIT. MANY OF THEM ARE BEAUTIFULLY PAINTED

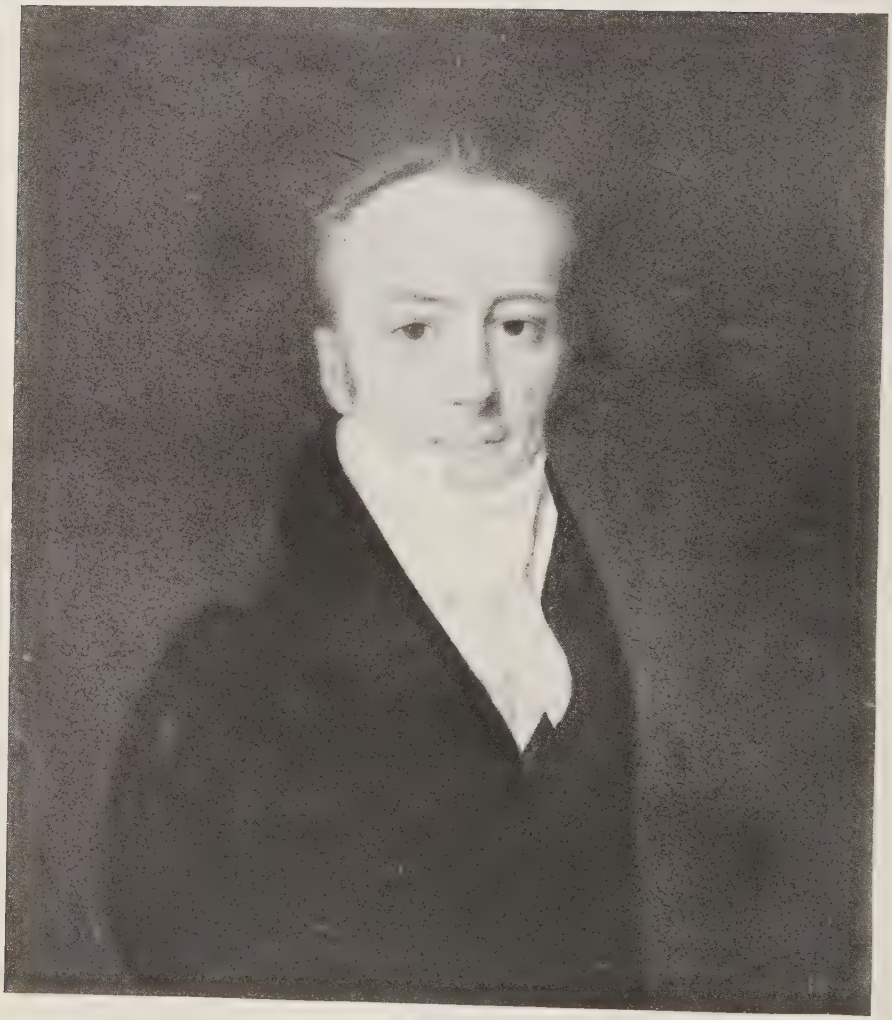
2. THE HOME OF THE EXPEDITION, PALAIS HAMILCON AT SIDI-BOU-SOUD



1. THE FIRST CLUE TO A PUNIC RUIN ITSELF. PUNIC PILASTER NOW IN THE NATIONAL MUSEUM AT TUNIS



2. INSCRIPTION BEARING A GENEALOGY OF 16 PUNIC NAMES AND A TERRIBLE MALEDICTION. THIS IS THE STELE THAT WAS COMMUNICATED TO THE FRENCH INSTITUTE BY THE ABBÉ CHABOT, JUNE, 1924. IT IS NOW IN THE NEW MUSEUM



JAMES SMITHSON

THE SMITHSONIAN INSTITUION

[With 21 plates]

"The advancement of the highest interests of national science and learning and the custody of objects of art and of the valuable results of scientific expeditions conducted by the United States have been committed to the Smithsonian Institution. In furtherance of its declared purpose—for the 'increase and diffusion of knowledge among men'—the Congress has from time to time given it other important functions. Such trusts have been executed by the institution with notable fidelity. There should be no halt in the work of the Institution, in accordance with the plans which its Secretary has presented, for the preservation of the vanishing races of great North American animals in the National Zoological Park. The urgent needs of the National Museum are recommended to the favorable consideration of the Congress." (President Roosevelt's first message to Congress.)

In the popular mind, the Smithsonian Institution is a picturesque castellated building of brown stone, containing birds and shells and beasts and many other things, situated in a beautiful park at Washington, with another large adjacent building, often called "the Smithsonian National Museum." The Institution is likewise supposed to have a large corps of learned men, all of whom are called "professors" (which they are not), whose time is spent in writing books and making experiments and answering all kinds of questions concerning the things in the heavens above, the earth beneath, and the waters under the earth.

Contrast this popular notion with the facts. The Smithsonian Institution is an "Establishment," created by an act of Congress, which owes its origin to the bequest of James Smithson, an Englishman, a scientific man, and at one time a vice president of the Royal Society, who died in Genoa in 1829, leaving his entire estate to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men."

After 10 years of debate in Congress, turning partly on the question whether the Government ought to accept such a bequest at all and put itself in the unprecedented position of the guardian of a

ward, Congress accepted the trust and created by enactment an "Establishment" called by the name of the Smithsonian Institution, consisting of the President of the United States, the Vice President, the Chief Justice of the United States, and the members of the President's Cabinet. It has also a secretary, the executive officer of the Institution, who is also the keeper of the National Museum.

Smithson's money, which amounted to over half a million dollars, and later to three-quarters of a million, a great fortune in that day of small things, was lent to the United States Treasury, the Government agreeing to pay perpetually 6 per cent interest upon it.

In the fundamental act creating the Institution, Congress, as above stated, provided that the President and the members of the Cabinet should be members of the Institution—that is, should be the Institution itself—but that nevertheless it should be governed by a Board of Regents, composed of the Vice President and Chief Justice of the United States, three Regents to be appointed by the President of the Senate (ordinarily the Vice President), three by the Speaker of the House of Representatives, and six to be selected by Congress; two of whom should be residents of the District of Columbia, and the other four from different States, no two being from the same State. The fundamental act further provides that the secretary of the Institution already defined shall also be the secretary of the Board of Regents. The Museum is primarily to contain objects of art and of foreign and curious research; next, objects of natural history, plants, and geological and mineralogical specimens belonging to the United States. Provision is also made for a library, and the functions of the Regents and of the secretary are defined.

The preamble of this bill states that Congress has received the property of Smithson and provided "for the faithful execution of said trust agreeable to the will of the liberal and enlightened donor." It will thus be seen that the relations of the General Government to the Smithsonian Institution are most extraordinary, one may even say unique, since the United States solemnly bound itself to the administration of a trust. Probably never before has any ward found so powerful a guardian. The Smithsonian is neither endowed nor maintained by Government appropriation, though the Government entrusts the administration of several of the publicly supported bureaus to its care.

Very eminent men have served upon the Board of Regents, both as members of the Government and from civil life. Among them may be found Louis Agassiz, Alexander Dallas Bache, George Bancroft, Rufus Choate, James Dwight Dana, Asa Gray, Gen. Mont-

SMITHSONIAN BUILDING

ARTS AND INDUSTRIES BUILDING, U. S. NATIONAL MUSEUM

NATURAL HISTORY BUILDING, U. S. NATIONAL MUSEUM. SOUTH FRONT

JOSEPH HENRY

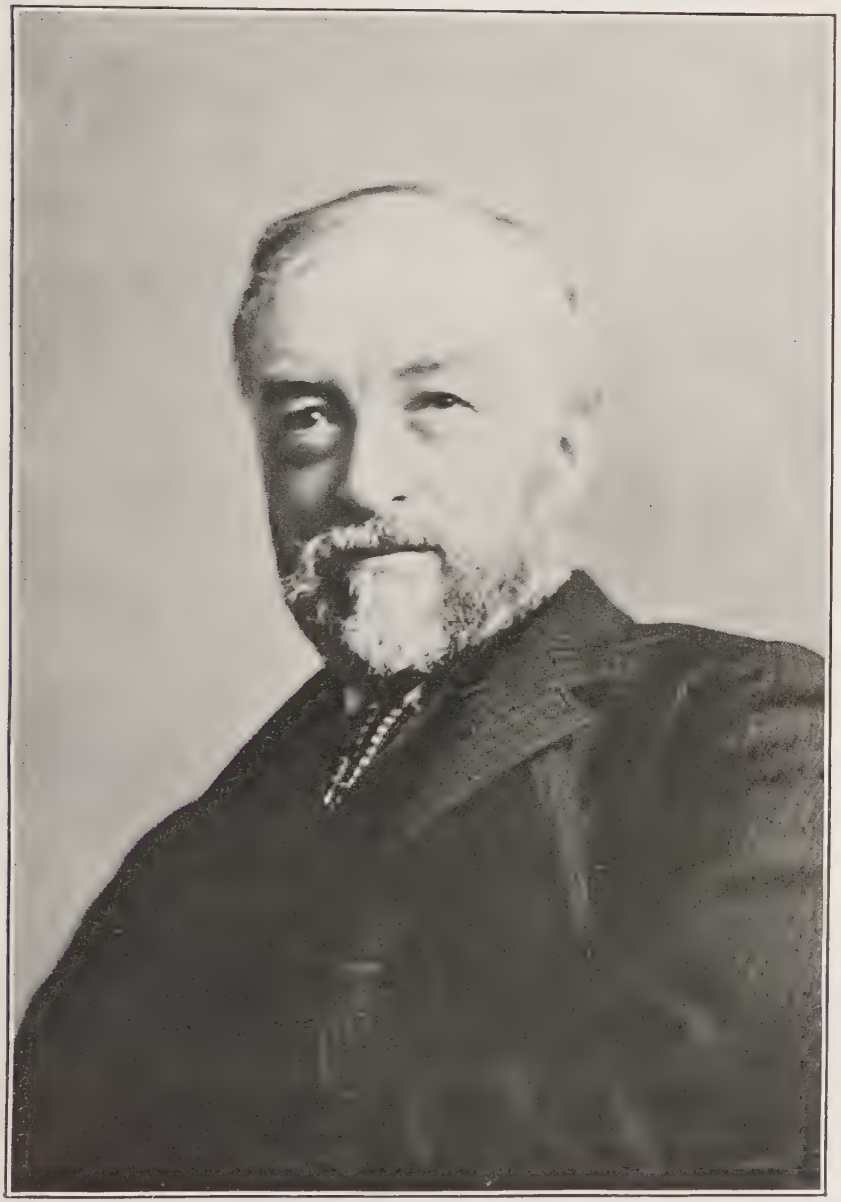
Secretary of Smithsonian Institution, 1846–1878

SPENCER FULLERTON BAIRD

Secretary of Smithsonian Institution, 1878–1887

GEORGE BROWNE GOODE

Assistant Secretary of Smithsonian Institution, 1887–1896



SAMUEL PIERPONT LANGLEY

Secretary of Smithsonian Institution, 1887-1906

CHARLES DOOLITTLE WALCOTT

Present Secretary of Smithsonian Institution

gomery C. Meigs, President Noah Porter, Gen. William Tecumseh Sherman, Alexander Graham Bell, the eminent Chief Justices of the United States, and Presidents Fillmore, Johnson, Arthur, Roosevelt, and Coolidge, as well as the President of the Confederacy, Jefferson Davis.

SECRETARY JOSEPH HENRY, 1846–1878

The first meeting of the Regents occurred on September 7, 1846, and in the autumn of the same year they elected as secretary Joseph Henry, then a professor at Princeton, known for his extraordinary experiments on the electromagnet and other subjects relating to electricity. His name is perpetuated in the term "henry," the unit of electrical self-inductance. Under his guidance the Institution took shape. Of another great man of science, the biographer would enumerate his classical publications and epoch-making experiments. Of Henry's life and work from 1846 till his death in 1878, the great experiment was the Smithsonian Institution, and his memoirs its publications. Yet he was also in the forefront of science in America, and an honored president of the National Academy of Sciences.

The work of the Smithsonian at first consisted, in the main, of the publication of original memoirs, containing actual contributions to knowledge, and their free distribution to important libraries throughout the world; of giving popular lectures in Washington, publishing them, and distributing them to libraries and individuals; stimulating scientific work by providing apparatus and by making grants of money to worthy investigators; and cooperating with Government departments in the advancement of work useful to the General Government. These were the principal methods employed by Henry to carry out the purposes of Smithson, for the increase and diffusion of knowledge. At the Smithsonian, too, were initiated certain studies which afterwards became most fruitful and have resulted in important Government work, most of the present scientific activities of the Government having grown out of these investigations or been stimulated by them, such as, for instance, the present Weather Bureau. The beginning of cooperation in library work was at the Institution. Experiments in fog signaling, in the acoustics and ventilation of public buildings, and in numerous other subjects were inaugurated. In fact, in these earlier days, with one or two exceptions, the Smithsonian was the sole representative of active scientific work directly or indirectly connected with the United States Government. Its influence upon the character of private scientific work, too, was very great, since half a century or more ago the avenues for publishing were few, and the funds for the purpose slender.

SECRETARY SPENCER FULLERTON BAIRD, 1878–1887

In 1850, Spencer Fullerton Baird, a distinguished naturalist, was elected assistant secretary of the Institution. After Henry's death, in 1878, he succeeded him as secretary, and continued in that office until his own death in 1887.

Secretary Baird was for 37 years continually in the scientific service of the Smithsonian Institution and the Government. He developed the National Museum. An opportunity never to come again was presented by the many great expeditions sent by the Government into virgin fields about this time. Railroads were being built, territories surveyed, arctic and antarctic explorations were being made. The Army had numerous outposts in the then western wilderness. Baird seized the opportunity and made the most of it. He was himself an indefatigable student of the collections, but even more, he trained a school of young men almost as enthusiastic as himself, to whom, after him, is owing the great success of the museum. He was especially instrumental in organizing the system of international exchange of publications which remained under his direct charge until his death. He was the moving spirit in the establishment and organization of the United States Fish Commission, and its commissioner from its foundation until his death. Methods which he invented for fish culture, and the studies of the natural history of our waters inaugurated by him, were epoch making. The marine biological station at Woods Hole, Mass., originated with him.

From 1875 Doctor Baird was greatly aided by a young and enthusiastic naturalist, George Brown Goode, who was appointed assistant secretary in 1887. Doctor Goode's untimely death in 1896 was a heavy blow to the whole Institution and especially to the National Museum.

SECRETARY SAMUEL PIERPONT LANGLEY, 1887–1906

Doctor Langley was the pioneer of the new astronomy. His wonderful vision and powers of delineation had made his early eye observations of the sun's surface notable, but the chief contribution which he made to astrophysics was the invention of the bolometer, an extraordinarily sensitive electrical thermometer, and the application of it to the study of the energy of the sun, the distribution of its radiation in the spectrum, and the similar investigation of the radiation of the moon. He established the Astrophysical Observatory at the Smithsonian Institution to carry on this type of investigations. He is best known to the public for his studies on aviation. Rescuing from ridicule this later highly important subject, he made careful

investigations of the physics of mechanical flight, and as early as 1896 built large successful flight models with which he conducted flights of nearly a mile. His later-constructed, man-carrying machine unfortunately failed of a successful launching, but the device was undoubtedly capable of flight, as was demonstrated in 1914, when it was flown by Curtiss at Hammondsport. Doctor Langley's interest in the preservation of rapidly disappearing forms of the larger animals of the United States led to the establishment during his administration of the National Zoological Park.

SECRETARY CHARLES DOOLITTLE WALCOTT. ELECTED 1907

The fourth secretary, Dr. Charles Doolittle Walcott, elected in 1907, had been in the service of the Geological Survey for over a quarter of a century, and from 1891 its director. His researches had covered many lines but had been preeminent in Cambrian paleontology. Our knowledge of the earliest fossil forms of life is indelibly associated with the name of Walcott. Always forward looking, he had exercised a highly salutary and important influence on the developments of forestry and reclamation, and had been the trusted adviser of presidents and legislators. He was also the moving spirit in the establishment of the Carnegie Institution, and has continued for many years highly influential on its board of trustees. During the World War, his services on numerous committees and in coordination of scientific activities were eminent. From 1917 to 1923, he was president of the National Academy of Sciences, and in 1923 was president of the American Association for the Advancement of Science. During Secretary Walcott's administration the National Gallery of Art and the Freer Gallery were added as branches of the Smithsonian Institution.

THE NATIONAL MUSEUM

Gradually, out of the collections which had been kept in the Patent Office, the private collections of Smithson, and of appropriations of his money made by the Regents, and largely also through the results of the great exploring expedition of Captain Wilkes, there grew up a Smithsonian museum, one which was exclusively cared for from the Smithson fund. Partly through the greater activity of the Government surveys, partly through the gifts of private individuals, and also through the valuable objects presented to the United States Government by foreign nations at the close of the Centennial at Philadelphia in 1876, there was brought about the establishment of what is now known as the United States National Museum of the Smithsonian Institution, which is under

control of the Regents of the Institution. Great buildings have been provided by the Government for the Museum, and it now receives direct support from Congress. This Museum has now the material belonging to the original Institution collected by the Smithsonian's own observers, together with much more secured through the General Government, making in all almost 10,000,000 specimens. These constitute the foremost collection in the world in everything that relates to the natural history, ethnology, geology, and paleontology of the United States, besides containing many valuable series in all these sciences from other countries. The collections have been visited by over 20,000,000 persons and the Institution has carried selections of its specimens to every large exhibition held in the United States, and distributed over 1,000,000 specimens to colleges and academies, thus powerfully stimulating the growth of museums large and small in every section of the country.

THE NATIONAL GALLERY OF ART

In the year 1846, in the act of organization of the Smithsonian Institution, the Congress of the United States directed the formation of a gallery of art for the Nation. Even at a somewhat earlier date it gave encouragement to such a project by granting an act of incorporation to a private society, whose collections were eventually to be ceded to the United States. The assembling of art objects under the chartered association began in 1840, and under the specific provision for a gallery in 1849. The two collections were united in 1862, since which time the subject of art as a museum feature under the Government has continued in charge of the Smithsonian Institution, in accordance with the terms of its establishment in 1846.

Mrs. Harriet Lane Johnston, niece of President Buchanan, and mistress of the White House during his term of office, assembled at her home in Washington a small collection mainly of paintings, including examples of the work of several distinguished masters, which, upon her decease in 1903, it was found had been bequeathed to the National Gallery of Art when one should be established by the Government. In ignorance of the fact that the necessary means for carrying out her wishes were already in existence, Mrs. Johnston named a temporary custodian, but under conditions that were not acceptable. In a friendly suit which followed to settle some doubtful clauses in the testament, it was decreed by the Supreme Court of the District of Columbia that the collection of art contemplated in the act of establishment of the Smithsonian Institution was, within the meaning and intent of the law, the National Gallery of Art. The collection of Harriet Lane Johnston was accordingly awarded to the Institution, and was received at the beginning of August, 1906.

To say that this acquisition raised the department of art to a standard, if not to a size, appropriate to a National Gallery would be but a feeble expression of its import, or of that of the court's decision. The generous act of Mrs. Johnston and the court's ruling met with spontaneous and gratifying approbation in all parts of the country, and the gifts which it has led to up to the present time have exceeded the most extravagent expectations.

The national collections have increased rapidly, chiefly through gifts and bequests of art works by patriotic citizens. Until the beginning of the year 1920–21, no appropriation had been made for the gallery or for the purchase of art works, and no provision for the employment of a salaried curator or other employees of the gallery, all works of art being associated with the department of anthropology of the National Museum.

Fortunately a liberal private fund became available in 1919 for the increase of the collections. The will of the late Henry Ward Ranger provided the sum of $200,000, the interest of which is to be devoted to the purchase of works of art for the National Gallery, the carrying out of the bequest being intrusted to the National Academy of Design. The provision is as follows:

> All pictures so purchased are to be given by the council to art institutions in America, or to any library or other institutions in America maintaining a gallery open to the public, all such gifts to be upon the express condition that the National Gallery at Washington, administered by the Smithsonian Institute, shall have the option and right, without cost, to take, reclaim, and own any picture for their collection, provided they exercise such option and right at any time during the five-year period beginning 10 years after the artist's death and ending 15 years after his death; and, if such option and right is not exercised during such period, the picture shall remain and be the property of the institution to which it was first given.

By the action of the Sixty-sixth Congress in providing "for the administration of the National Gallery of Art by the Smithsonian Institution, including compensation of necessary employees and necessary incidental expenses," its connection with the Museum was severed and it became the seventh Government bureau under the administration of the Institution on July 1, 1920.

On May 27, 1921, the Board of Regents of the Institution, having the future of the gallery in mind, took the initial steps in the establishment of the National Gallery of Art Commission, formulating a plan of organization and naming a committee of eminent men interested in the fine arts to perfect the organization.

The value of the National Gallery collections already in hand is estimated at several million dollars, their acquirement being due to the generous attitude of American citizens toward the National Gallery of Art. It can hardly be doubted that when a building is

provided in which contributions can be cared for adequately, and exhibited to the public in the manner they deserve, many collectors seeking a permanent home for their treasures will welcome the opportunity of placing them in the custody of a national institution. The providing of a suitable building for the gallery is all that is necessary to make Washington in the years to come an art center fully worthy of the Nation.

THE FREER GALLERY OF ART

The collections installed in the Freer Gallery of Art were brought together by Charles Lang Freer, of Detroit, Mich. They represent the results of Mr. Freer's personal study and acquisition over a period of about 35 years, the earliest of his purchases incorporated in the collections dating from the later eighties.

During the administration of President Roosevelt, these collections were presented by Mr. Freer to the Nation, with the understanding that they should be placed under the direction of the Smithsonian Institution, and on May 5, 1906, the formal deed of gift to the Smithsonian was executed.

The building in which the collections are now installed was given also by Mr. Freer, who requested that it be used exclusively for his collections. In accepting this gift, the Government agreed to care for and maintain the building and collections at the public expense, although in addition to these provisions, Mr. Freer created an endowment, the income from which was to be used for certain specified activities and developments which he wished to have carried on after his death independently, if need be, of congressional appropriations. It was, furthermore, his expressed desire that his gift should become a unit of the National Gallery of Art which he hoped would be erected in Washington in the near future, and to which he felt confident additional units would be given by other collectors who might think, as he did, that such a foundation at Washington, under the control and direction of the Government, would mean the development of an important center for cultural research in both art and science.

Mr. Freer was convinced that the more nearly a cultural object of any civilization expresses the underlying principles of artistic production in soundness of thought and workmanship, the more nearly it takes its place with other objects of equally high quality produced by any other civilization; and with that in view, he was intent upon bringing together such expressions of western and eastern cultures as seemed to him to embody at their best those characteristics which he believed to be inherent in all works of art.

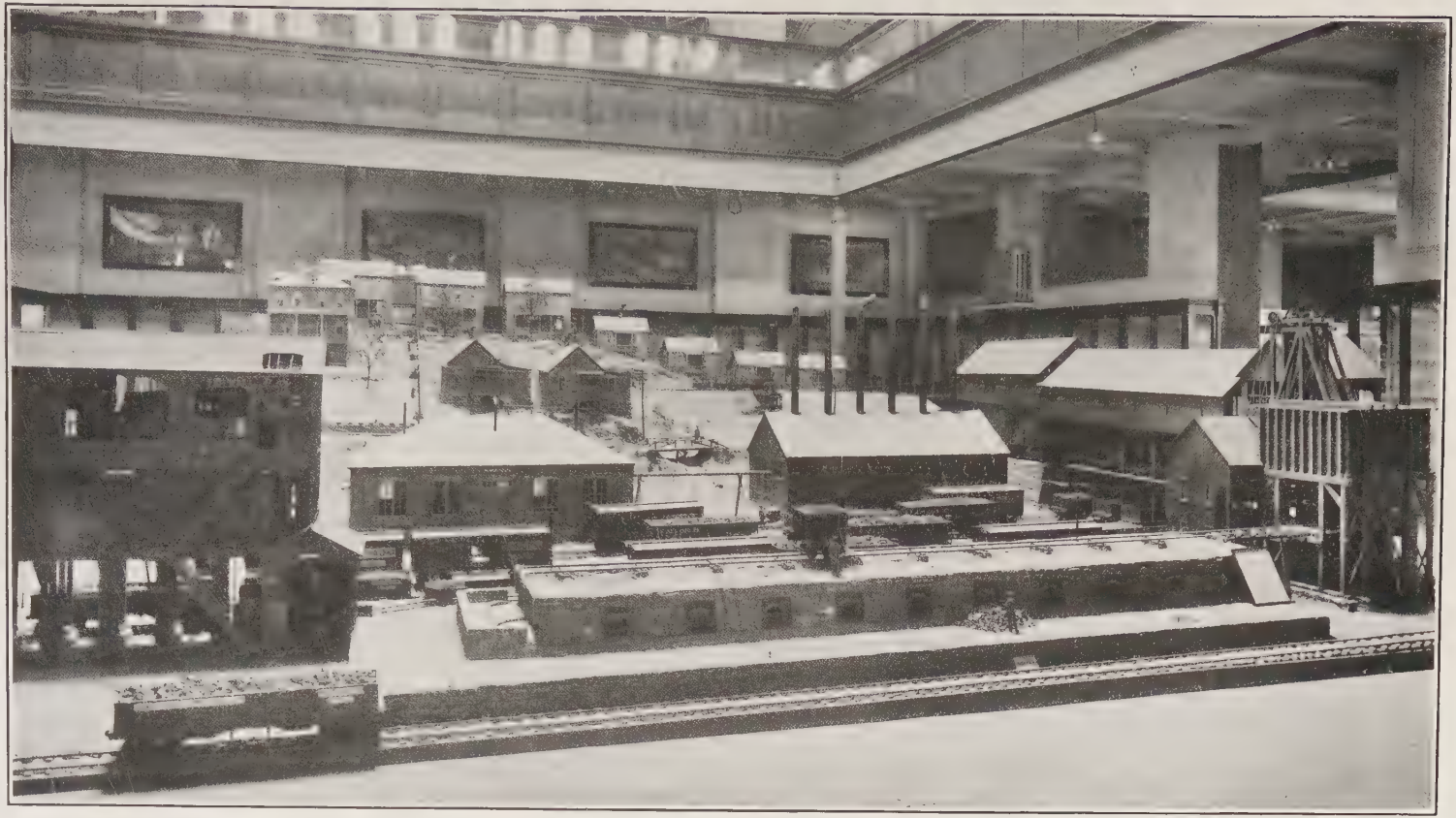
From the West, he acquired principally American paintings by men, inheritors of European traditions, in whose work he found

EXHIBITION OF FOSSIL VERTEBRATES, U. S. NATIONAL MUSEUM

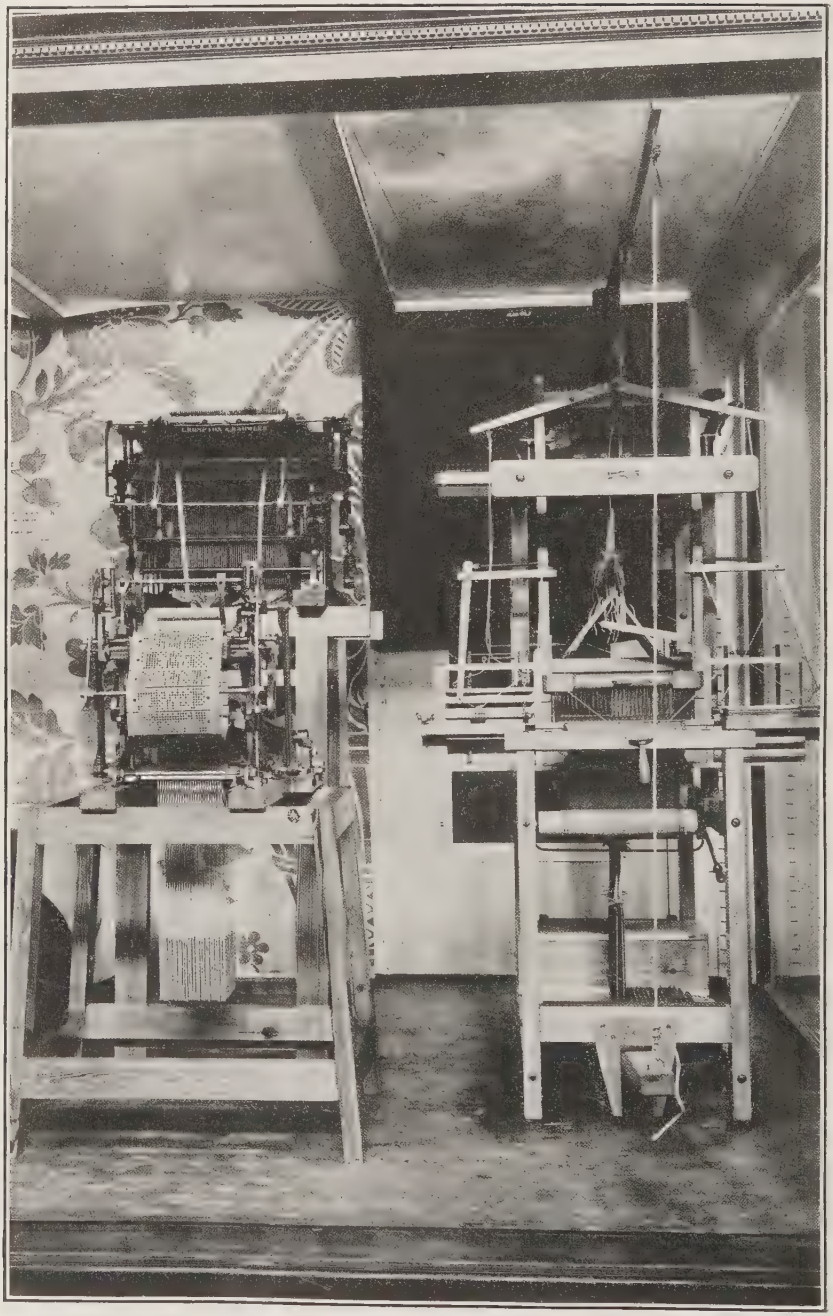
EXHIBITION OF FOSSIL VERTEBRATES, U. S. NATIONAL MUSEUM

GROUP OF AFRICAN LIONS FROM ROOSEVELT EXPEDITION, U. S. NATIONAL MUSEUM

EXHIBITION GROUP OF BERING STRAIT ESKIMO, U. S. NATIONAL MUSEUM

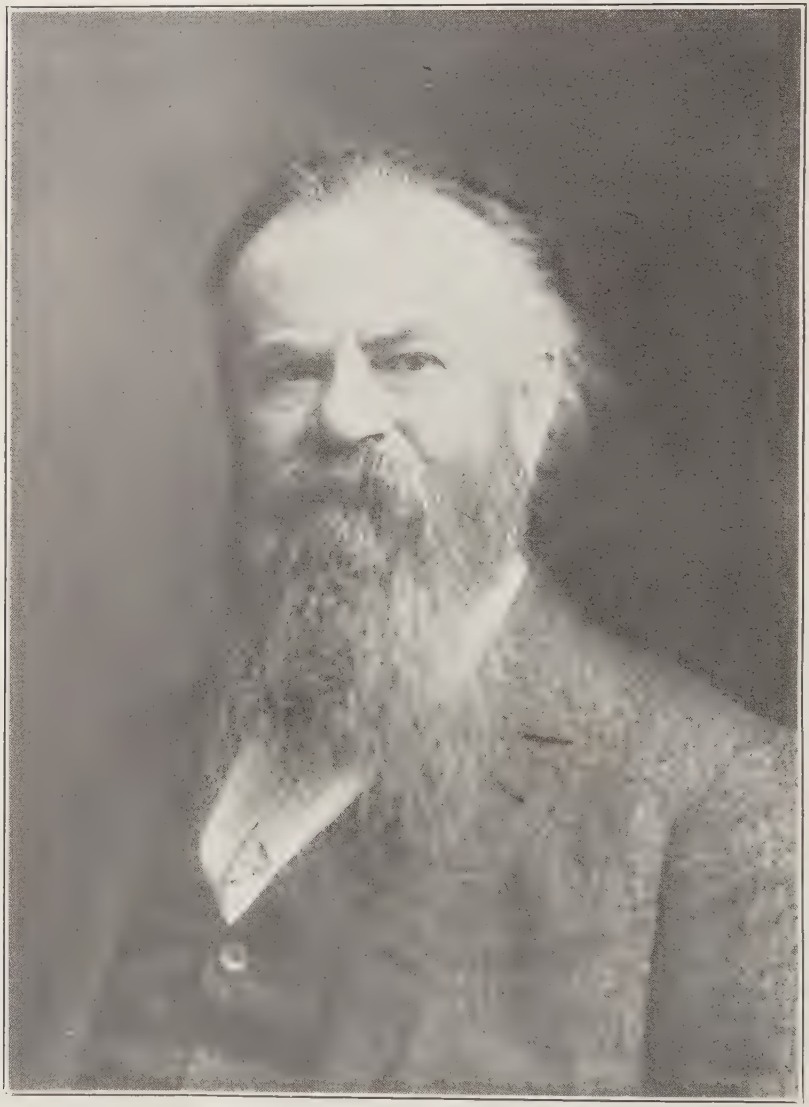


WORKING MODEL OF COAL MINE, U. S. NATIONAL MUSEUM



JACQUARD MACHINES, U. S. NATIONAL MUSEUM

FREER GALLERY OF ART



MAJOR JOHN WESLEY POWELL

Director, Bureau of American Ethnology, 1879–1902

qualities and tendencies sympathetic with those of earlier painters in China and Japan.

From the East, he gathered paintings, potteries, sculptures in stone, in wood and in lacquer, bronzes, jades, and objects of various other materials. The Chinese field is represented by the largest number of objects covering the longest period of time, but Japan, Korea, Persia and the Near East are represented liberally.

The Freer Gallery Building, the Freer art collections, and the endowment which Mr. Freer provided, represent many millions of dollars, so that this is not only the largest benefaction ever entrusted to the Smithsonian Institution, but the most generous gift ever made to art.

THE BUREAU OF AMERICAN ETHNOLOGY

The Bureau of American Ethnology was organized in 1879 and placed by Congress under the supervision of the Smithsonian Institution. It was directed that all the archives, records, and materials relating to the Indian tribes collected by the Survey of the Rocky Mountain Region under the auspices of the Interior Department should be transferred to the Institution for use by the bureau. Prof. Spencer F. Baird, Secretary of the Institution, recognizing the great value of Maj. J. W. Powell's services in initiating researches among the western tribes, selected him as the person best qualified to organize and conduct the work.

The National Government had already recognized the importance of researches among the tribes. President Jefferson, who planned the Lewis and Clark expedition of 1804–1806, "for the purpose of extending the internal commerce of the United States," especially stipulated, in his instructions to Lewis, the observations on the native tribes that should be made by the expedition for the use of the Government. The Government also aided the publication of Schoolcraft's voluminous work on the Indians. The various War Department expeditions and surveys had reported on the tribes and monuments encountered in the West; the Hayden Survey of the Territories had examined and described many of the cliff dwellings and pueblos, and had published papers on the tribes of the Mississippi Valley; and Major Powell, as chief of the Survey of the Rocky Mountain Region, had accomplished important work among the tribes of the Rio Colorado drainage in connection with his geological and geographical researches, and had commenced a series of publications known as Contributions to North American Ethnology. The Smithsonian Institution had also taken an active part in the publication of the results of researches undertaken by private students. The first volume of its Contributions to Knowledge is The Ancient

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

The Regents of the Smithsonian Institution authorized Secretary Henry to suggest, at the Glasgow meeting of the British Association for the Advancement of Science in 1855, the formation of a catalogue of scientific memoirs. The Royal Society of Great Britian approved the suggestion and secured a grant from the British Government, under which many volumes of such a catalogue appeared. In the first volume we read: "The present undertaking may be said to have originated in a communication from Dr. Joseph Henry, Secretary of the Smithsonian Institution."

In March, 1894, the Royal Society issued a circular to learned institutions throughout the world proposing a great international scientific subject catalogue. At the invitation of the British Government the United States was represented, through the Smithsonian Institution, in 1895, in a conference on this matter. The project finally took shape in 1900 as the International Catalogue of Scientific Literature, and by the assistance of the Smithsonian Institution, sufficient private subscriptions were secured in the United States, in addition to those received from other countries, to warrant the publication of the work in England.

Until 1906 the cards representing publications of the United States were prepared by the Smithsonian Institution at the cost of its private funds. Since 1906, the Regional Bureau for the United States has been maintained at the Smithsonian Institution under Government appropriations.

PUBLICATIONS

"The diffusion of knowledge" is accomplished by the Smithsonian Institution by generous correspondence, in which it annually answers thousands of inquirers, and through its various series of publications, which have been voluminous during 80 years. There being no restriction in scope, every branch of science has been dealt with, including anthropology, ethnology and archeology, botany, zoology, mechanics and aeronautics, physics, chemistry, geology, astronomy and astrophysics, meteorology, physiology, and many other subjects. In all, over 5,300,000 copies and parts have been distributed to institutions and private individuals, these works forming in themselves a scientific library in all branches. Its publications are probably the most widely known phase of the Institution's activity, and it is certain that a great impetus has been given to scientific progress in this country through their use by scientists, research workers, teachers, students, and all others engaged in the increase and promotion of knowledge.

The Smithsonian series of tables—Physical Tables, Meteorological Tables, Geographical Tables, and Mathematical Tables—have long

MAMMAL HOUSE, NATIONAL ZOOLOGICAL PARK

1. FLIGHT CAGE, NATIONAL ZOOLOGICAL PARK

2. SWAN IN NATIONAL ZOOLOGICAL PARK

FORD IN NATIONAL ZOOLOGICAL PARK

2. POLAR BEAR CAGE, NATIONAL ZOOLOGICAL PARK

HODGKINS MEDAL OF SMITHSONIAN INSTITUTION

been standard works of reference, and the continued demand for them has necessitated several editions of each. "Smithsonian Mathematical Formulæ and Tables of Elliptic Functions" has recently been added to this series.

The Smithsonian publications, together counting a total of well over 250,000 printed pages since 1846, are as follows: (1) Annual Reports of the Board of Regents to Congress, containing every year a general appendix composed of popular articles illustrating recent progress in every branch of science and research; (2) Smithsonian Contributions to Knowledge, extended memoirs in quarto form embodying the results of important original research; (3) Smithsonian Miscellaneous Collections, containing scientific papers on the most diversified subjects, some of which have considerable popular interest; (4) Annual Reports of the National Museum; (5) Bulletins of the National Museum (including Contributions from the National Herbarium), which contain accounts of original research by the staff of the Museum or on the Museum collections; (6) Proceedings of the National Museum, technical papers on the collections, and routine scientific work of the Museum; (8) Annual Reports of the Bureau of American Ethnology, which are enriched by accompanying papers on ethnological and archeological subjects; (9) Bulletins of the Bureau of American Ethnology, containing accounts of research by members of the staff of the bureau on the customs, languages, and archeology of the American Indians; (10) Annals of the Astrophysical Observatory, which are extended accounts of the results obtained from the original investigations of the Observatory; and (11) Catalogues of Collections of the National Gallery of Art. These various publications may be seen on the shelves of every important library in the world.

LIBRARY

Partly by purchase, but in the main by exchange for these publications, the Institution has assembled a library of over 900,000 volumes, principally of serial publications and the transactions of learned societies, which is one of the notable collections of the world. The major portion of it, now over 800,000 volumes, has been since 1866 deposited in the Library of Congress, with which establishment the most cordial and mutually helpful relations exist. The remainder, about 100,000 volumes, is kept at the Smithsonian and its branches for easy reference.

INTERNATIONAL EXCHANGES

As another means of diffusing knowledge there was early established the Bureau of International Exchanges, originally intended simply for the proper distribution of the Smithsonian's publications, but which gradually assumed very wide proportions, becoming no

less than an arrangement with learned societies throughout the world to reciprocally carry free the publications of learned societies, or of individual scientific men, intended for gratuitous distribution. This system was afterwards taken up by various governments which, through treaties, bound themselves to exchange their own publications in the same way. Since the inauguration of this service, over 16,000,000 pounds of books and pamphlets have been carried to every part of America and to all other countries of the world. The Institution, existing not only for America, in which it has over 20,000 correspondents, but for the world, has throughout Europe, Asia, Africa, and the islands of the sea, over 40,000 correspondents—more outside the United States than within—justifying the words "Per Orbem" as the device on the Smithsonian seal. For many years carried on solely at the expense of the Smithsonian private funds, a small yearly grant from the Government for the exchanges was begun in 1881. Since the year 1886 the cost of the exchanges has been mainly borne by congressional appropriations.

EXPEDITIONS, EXPLORATIONS, AND EXHIBITIONS

In all its history the Smithsonian Institution has been prominently connected with the exploration of little-known districts of the earth, and the collection of specimens and scientific data from them. In many of the Government surveys the Institution has cooperated. The great National Herbarium, which for a long time has been housed by the Smithsonian Institution, has been enriched by its expeditions. The famous Roosevelt African Expedition, which brought back a rich collection of African fauna, was carried out under Smithsonian auspices. Extensive collections representing the East and West Indies, Australia, and Southeast Asia have been made for the Smithsonian Institution for many years by the generosity of Dr. William L. Abbott. Archeology, astronomy, botany, ethnology, geology, paleontology, zoology, and other sciences have all benefited by the journeys of members of the Institution's staff to distant lands. Notable among such expeditions are the solar eclipse expeditions, the solar radiation expeditions, Doctor Fewkes's explorations of prehistoric American ruins in the southwest, and Doctor Walcott's studies of Cambrian fossils in the Canadian northwest.

The Smithsonian Institution has participated prominently in almost all of the large expositions held in the last 50 years in America and Europe. Very numerous diplomas and medals attest the appreciation which its exhibits evoked.

For the promotion of education large numbers of specimens have been distributed to schools and colleges throughout our country. These specimens are fully labeled and described in a way to assist in the instruction of pupils.

THE HODGKINS AND LANGLEY MEDALS

The Hodgkins gold medal was established by the Smithsonian Institution to be awarded for important contributions to the knowledge of the nature and properties of atmospheric air, or for practical applications of existing knowledge to the welfare of mankind. It was first bestowed, April 3, 1899, on Sir James Dewar, F. R. S., and second, October 28, 1902, on Prof. J. J. Thomson, F. R. S.

The Langley medal was established in memory of the late Secretary Samuel Pierpont Langley and his contributions to the science of aerodromics, "to be awarded for specially meritorious investigations in connection with the science of aerodromics and its application to aviation." This medal was presented in 1910 to the brothers Wilbur and Orville Wright, and in 1913, to Mr. Glenn H. Curtiss and M. Gustave Eiffel.

THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

In the year 1915, the Government established the National Advisory Committee for Aeronautics, in which representatives of the Army and the Navy, the Weather Bureau, the National Bureau of Standards, and others were drawn together for the promotion of the national defence. Secretary Walcott, of the Smithsonian Institution, acted as a member and chairman from its organization, and the meetings were often held at the rooms of the Institution.

CONCLUSION

As we thus briefly survey the history of the Smithsonian Institution, its past achievements, and its present development, we can not fail to be tremendously impressed by the fruitfulness of Smithson's bequest. An investment in science is as sure as a United States bond. All history, and especially the history of our own time, proves it. If investigation had always been limited to subjects promising to have utility, we should still be in the dark ages. The enlightenment of the human mind brought about by the study of astronomy, for instance, has a value not to be measured by dollars and cents, but by the safety of life and property from religious persecution and by the advance from superstition and ignorant fear of nature. On the other hand, it would be easy to cite many investigations of apparently merely curious and trivial phenomena which later on came to have commercial utility. One will suffice. As late as 1890 no "practical man" would have dreamed of investigating the conduction of electricity through rarefied gases. Röntgen's discovery of X rays in 1895 was not in the least influenced by utility, but came out of pure research work in that field. Think of X-ray hospital work nowadays! Moreover, every department store car-

ries radio outfits, with their thermionic amplifiers, which also are the children of that same line of pure research.

Hertzian waves have become radio; Pasteur's bacilli have led up to the Mayo brothers' surgery and the abolishment of yellow fever; Faraday's and Henry's electromagnets have become dynamos and telegraphs, and the whole world is revolutionized in a century by the discoverers who worked not for utilities but for knowledge. Yet it is a mean, stunted mind that sees only things like autos and electric lights as the foremost rewards and justification of science. What the sculpture of Phidias, the painting of Raphael, the music of Beethoven, the language of the Bible, are to the finer departments of the mind, such also, and quite as wholesome in their influence on private life and public conduct, are those studies of the atoms, the universe, and the march of life, which form science.

If any of our research institutions deserves public benefactions, most of all it is the national Smithsonian Institution. Founded by an Englishman, James Smithson, "for the increase and diffusion of knowledge among men," it has been the parent of the Weather Bureau, the Fish Commission, the National Museum, the Bureau of American Ethnology, the Geological Survey, the National Zoological Park, the Astrophysical Observatory, the Bureau of International Exchanges (of scientific intelligence), and the National Gallery of Art; it has contributed largely to the Library of Congress and has had a part in many other valuable enterprises. In its reports and technical papers the inquirer may find in accurate form, sometimes popularly, sometimes technically expressed, the whole progress of human knowledge. Not only that, but in a daily correspondence which taxes its small force of experts and clerks, it has answered hundreds of thousands of inquiries for useful or technical information. Though some of the bureaus just named have split away from the parent organization, the institution is still charged by Congress with the care of eight of them. These administrative duties employ much time of the staff and in some measure prevent the promotion of projects for the advancement of science.

Liberally endowed at the beginning, the resources of the Smithsonian Institution have not kept pace with the growth of our country. Other research institutions have far outstripped this ward of the whole Nation in their means for carrying on the investigation of nature. Local pride seems to have outrun national pride in the promotion of great scientific endowments. Thus it remains that in the year 1925 the yearly income of the Smithsonian endowment still is less than $70,000, and totally inadequate to the opportunities which the institution's prestige and eminent connections are continually presenting for maintaining its beneficent service to humanity.

SIR ARCHIBALD GEIKIE

SIR ARCHIBALD GEIKIE[1]

By Sir Aubrey Strahan

[With 1 plate]

By the death of Sir Archibald Geikie on November 10, 1924, British geology has lost its leader, and the Geological Society its most eminent Fellow. From an early age to the end of his long life he made the interests of the society one of his first cares. Elected a Fellow in 1859, he served on the council in 1883 and for many subsequent years. He was a vice president in 1886–1888 and president in 1890–1892. On the occasion of the centenary of the society in 1907, he acceded to a generally expressed desire that he should preside for a second term (1906–1908), and on relinquishing the chair was elected foreign secretary. For many years he had been constant in his attendance at the meetings, and when advancing years rendered this impossible, he tendered his resignation; but, at the unanimous request of the council, he continued to perform the duties of the post to the end of his life.

He was born in Edinburgh on December 28, 1835. For the details of his early life we are indebted to his autobiography, "A Long Life's Work." This volume, which was published only a few months before his death, shows no signs of waning powers or of failing memory. In it he describes the innumerable functions in which he took a leading part, the appointments which he held, his travels, and some of the many honors that he received. He dwells, too, on the friends whom he made and on the encouragement which he received from them as a young man and in after-life; but more especially interesting to us is the revelation of the inner thoughts of a boy who, in obedience to a natural bent and rather to the alarm of his father, made geology the occupation of his life, and eventually attained the highest posts open to a man of science in this country.

A dormant love of geology was roused accidentally soon after he left school. The finding of a fossil plant in a block of limestone in Burdiehouse Quarry set his active mind speculating on the relics of

[1] Reprinted by permission from The Quarterly Journal of the Geological Society, Vol. LXXXI, No. 322, July 4, 1925.

past ages that were entombed in the crust of the earth, and from that moment the rocks and their fossils became increasingly the subject of his thoughts. He made the acquaintance of Robert Chambers, afterwards known to be the author of the "Vestiges of Creation," and of other geologists, and read every book on geology that he could lay hands on, deriving, however, a greater stimulus from the enthusiasm and literary charm of Hugh Miller's "Old Red Sandstone" than from some more informing works. But, more than by any book, he was inspired by his own study of the rocks near Edinburgh, with their abundance of fossils and of evidence of ancient volcanic outbursts.

Though the boy's bent was clearly indicated, his father found it difficult to believe that a study of geology could provide a livelihood. He arranged, therefore, that young Geikie should become a banker, after a preliminary training for two years in a lawyer's office. The interruption was brief, for the boy's heart was among the hills of Midlothian and far from the office. He was out in the field again long before the two years had elapsed. Determined, however, to pursue literary studies in addition to science, he matriculated at Edinburgh University in 1854 as a student of Humanity (that is, Latin), and although domestic circumstances prevented him from completing the course, he gained the reputation of being one of the best classical scholars of his year and the best writer of English prose among his class fellows. The literary ability thus shown proved to be one of the principal factors in his success in after life.

In the meantime Geikie had been prosecuting geological work in Skye with such success that he impressed the geologists of the day as a young man of unusual promise. When, therefore, recruits were inquired for by Sir Roderick Murchison, then Director General of the Geological Survey, he was warmly recommended by Hugh Miller. A walk over Arthur's Seat with Ramsay, at that time Local Director, took the place of the examination of later days, and the appointment was made in 1855. After a year's training in the field with Ramsay, the young geologist was regarded as competent, and was set to work in the surroundings of Edinburgh. He found time, nevertheless, to complete his work in Skye, and to write an account of it, which was communicated to this society in 1857.

This period he found to be the most studious of his life; but, however great might be the calls upon his endurance, he never failed to make time for companionship with the classical authors and with the best English writers from Chaucer to our own day. The spirit with which he was imbued in his field work is best expressed in his own words: "The work on which I was now engaged, and to

which I had dedicated my life, was not merely an industrial employment; the means of getting a livelihood; a pleasant occupation for mind and body. It often wore to me an aspect infinitely higher and nobler. It was in reality a methodical study of the works of the Creator of the universe, a deciphering of His legibly written record of some of the stages through which this part of our planet passed in His hands before it was shaped into its present form" (A Long Life's Work, pp. 55, 56). The deep joy that he felt in the study of nature had to be shared with others, and in 1858 he produced a little book, "The Story of a Boulder," the first of a long series by which he carried his message to all parts of the civilized world.

In 1860 it fell to Geikie to complete the Life of Edward Forbes, which had been left unfinished through the death of Prof. George Wilson. Some of Forbes's relations hesitated before intrusting the task to so young a man, but the book, when published in 1861, showed that the confidence felt in him had not been misplaced. This was the first of several biographies in which Geikie, with many a kindly touch, recorded the personalities and achievements of friends who had gone before him. It was followed in 1869 by the life of James David Forbes, in 1875 by that of Murchison, and in 1895 by that of Ramsay. In all of them his close touch with current geological research and his sound judgment enabled him to present a true estimate of the progress in science due to each of these distinguished men.

In 1871 the natural history professorship at Edinburgh University was divided into two, and geology with mineralogy became the subjects of a new professorship. Murchison offered to endow the new chair, on the understanding that he should nominate the first professor. He put forward Geikie's name, but the power to nominate was objected to by the Home Office as an infringement of the prerogative of the Crown, and the Science and Art Department considered it inadvisable that the posts of director of the geological survey of Scotland and the professorship should be held by the same man. The appointment was made nevertheless, mainly through the exertions of Lyon Playfair, at that time member for the university. During his tenure of this post, which lasted till he was appointed director general of the survey in 1882, Geikie did much to revive the renown of the old Scottish geological school. He had at first no lecture room to himself and no diagrams or specimens, but made use of the exceptional advantages offered by the neighborhood of Edinburgh to conduct geological excursions, which are still gratefully remembered by his old students.

In 1860 Murchison invited Geikie to accompany him to the Highlands, with the object of following up the conclusions to be drawn

from Charles Peach's discovery of Cambrian fossils in northwestern Sutherland. Writing in 1924, Geikie admits that this expedition "was a premature attempt * * * the true structure of the Highlands was far too complicated to be unraveled by desultory and hasty traverses." Neither he nor Murchison had been able to doubt the evidence of their eyes that in one section after another crystalline schists overlay fossiliferous Cambrian strata with what aversy which has been laid to rest for many years, and it will suffice to say that the apparent normal superposition with its far-reaching consequences found no acceptance with Nicol, Heddle, Callaway, Bonney, and others. Geikie, partly perhaps through loyalty to his chief, for long refused to give way, and it was not till Lapworth had made his exhaustive examination of the whole Durness-Erribol region that he admitted his error. Once convinced, he hastened to correct it. He intrusted the surveying of the region to B. N. Peach and J. Horne, who with their colleagues produced what was probably the most detailed and masterly study of overthrusting on a great scale that had ever been made.

The succession of strata in the Moffat and Girvan districts was determined in somewhat similar stages. There also it had been masked by earth movements. Faults and excessive plication had repeated the same beds over and over again, and it was only by detailed surveying and intensive study of the fossils that Lapworth unraveled the tangle. His predecessors had been content to leave as one group a series of strata varying extraordinarily in thickness and petrological character, and containing an admixture of fossils that were elsewhere characteristic of distinct formations. He reduced this enigmatical "group" to an orderly sequence, each member of which was distinct in character and fossils, and established correlation with other parts of the kingdom. It is interesting to see how closely these Highland controversies were paralleled in the United States. There the succession of the same rocks was in question, the same difficulties in determining it were encountered, and the same mistakes were made. The "Taconic System," founded in 1842, formed the subject of controversy for upwards of 60 years, until it was finally proved to consist of Cambrian and Silurian strata folded and faulted together in no sort of chronological order. That the first geologists to encounter problems so calculated to deceive should have failed to master them need cause no surprise. Rather should our sympathies be extended to pioneers who were faced with the impossible task of interpreting dislocations, the existence of which could be ascertained only by prolonged and detailed mapping. But we may admit that our sympathy might

have been warmer had Geikie, true lover of nature as he was, shown more cordiality in welcoming the elucidation of the truth.

There remains, however, to his credit a great record of original unchallenged work. He made a particular study of the composition and direction of transport of the Bowlder clay, and noted the occurrence in it of stratified beds which he attributed to temporary amelioration of climate. Originally an advocate of the iceberg theory, he abandoned it in favor of Agassiz's views on ice sheets, convinced by the work of his colleagues in Scotland and by what he saw in northern Norway. He recognized also among the Scottish mountains the existence of moraines and glacierborne blocks and the sites of glacial lakes as evidences of local glaciation during the last phase of the Glacial Period.

His great paper on the Old Red Sandstone of Western Europe, as a piece of masterly description, takes high rank in geological literature. His classification has in the main stood the test of time; but, with characteristic reluctance to change a view to which he had once committed himself, he persistently declined to remove the Caithness Flagstones from the Lower Old Red Sandstone, though they differed from that subdivision (as known in the Grampians) both in their fishes and in their plants. The flagstones appear in Geikie's map of Scotland as Lower Old Red, but on the geological survey maps as Middle Old Red Sandstone.

Volcanic episodes in the history of the earth had engaged Geikie's attention from the first, and in 1860 he presented to the Royal Society of Edinburgh a paper on "The Chronology of the Trap Rocks of Scotland," in which for the first time an attempt was made to arrange the volcanic periods evidenced in that country in geological sequence. In dealing with this subject he was not satisfied till he had acquired the necessary experience by visiting the volcanic regions of Auvergne, the Eifel, and Italy, and exploring the great lava fields of western America. In Auvergne, especially, the comparatively recent features displayed by volcanic energy enabled him to picture the aspect of the ancient vents and lava flows of the Firth of Forth. In the United States he found reason to adopt Richthofen's view that the flat beds of basalt were due to fissure eruptions, and applied this interpretation to the Tertiary volcanic plateaus of the West Highlands. He summed up his observations and conclusions in his standard work on the Ancient Volcanoes of Great Britain.

Unlike Lyell, Geikie gained most of his experience by his own observations in the field. In addition to the work done in his leisure time, he was for some years a member of the field staff of the geological survey, and after he had attained higher posts,

charged mainly with administrative duties, he was constant in inspection. On these occasions his quick grasp and wide experience enabled him to give much help to his colleagues, but at the same time he made full use of the opportunities for adding to his own knowledge. Scenery from the point of view of its origin and geological significance made a strong appeal to his poetic instincts. Born, bred, and trained in Scotland, he had gazed upon many a noble landscape, and had pondered over the vast effects of denudation and the characters imposed upon the features of the country by the passage of ice sheets. His views are embodied in "The Scenery of Scotland," published in 1865, a book as interesting to the nongeological reader as to the expert. All his lighter books, indeed, such as Geological Sketches at Home and Abroad and Scottish Reminiscences, were written in a style to appeal to a large circle of readers.

Late in life he interested himself in the early history of geology. The Founders of Geology, first published in 1897, could only have been written by one who had a wide acquaintance with ancient and modern literature. When called upon to deliver a presidential address to the Classical Association, he chose for his subject the evidence from Latin literature of the appreciation of nature by the Romans. Later on he further developed the theme, and visited Italy in order that he might himself study the landscapes on which the eyes of the Roman poets had dwelt.

Of all the calls made upon Geikie's untiring industry none was more severe than the production of his educational works. The "Advanced Textbook" is a storehouse of information and a monument to the sagacity with which he handled an enormous literature. Stupendous as was the labor involved, he found the preparation of the two little primers on geology and physical geography still more exacting—the phrasing was made the subject of many experiments on students before he could satisfy himself that he had secured the lucidity that was essential. The two small-scale geological maps of Scotland and England, respectively, prepared by him during his term of office on the Geological Survey, are admirable examples of the pains that he took to secure clearness and what he considered to be correct versions.

As a lecturer he had many experiences, both at home and abroad, before audiences of the most varied character, including the inmates of a deaf and dumb institution and the patients of the Morningside Lunatic Asylum. He was also one of that little band of distinguished men who lectured to working men in the theater of the Jermyn Street Museum. His wide reading enabled him to choose subjects to suit his hearers, and more than once he enlarged later in book

form on some research that he had taken up for the purposes of an address. Masterly and elegantly phrased as his lectures were, they never failed to interest; but in delivering them he was not the equal of many a far less able man in rousing enthusiasm in his audience.

His retirement from the Geological Survey in 1901 enabled him to increase his other activities. He had been elected to the Royal Society in 1865, had served twice on the council, and had held the posts of vice president in 1885–1887, and of foreign secretary in 1889–1893. After his retirement he served as secretary in 1903–1908 and was president in 1908–1912. In 1912 the society celebrated its two hundred and fiftieth anniversay, and it fell to Geikie to receive an unexampled gathering of distinguished men of science from all parts of the world, and to preside at the various functions. During this period of his life he wrote six or more books, besides bringing out new editions of his Advanced Textbook and several others. He had served on several departmental committees and on Royal Commissions; at the age of 85 he was appointed chairman of the Royal Commission on Trinity College, Dublin.

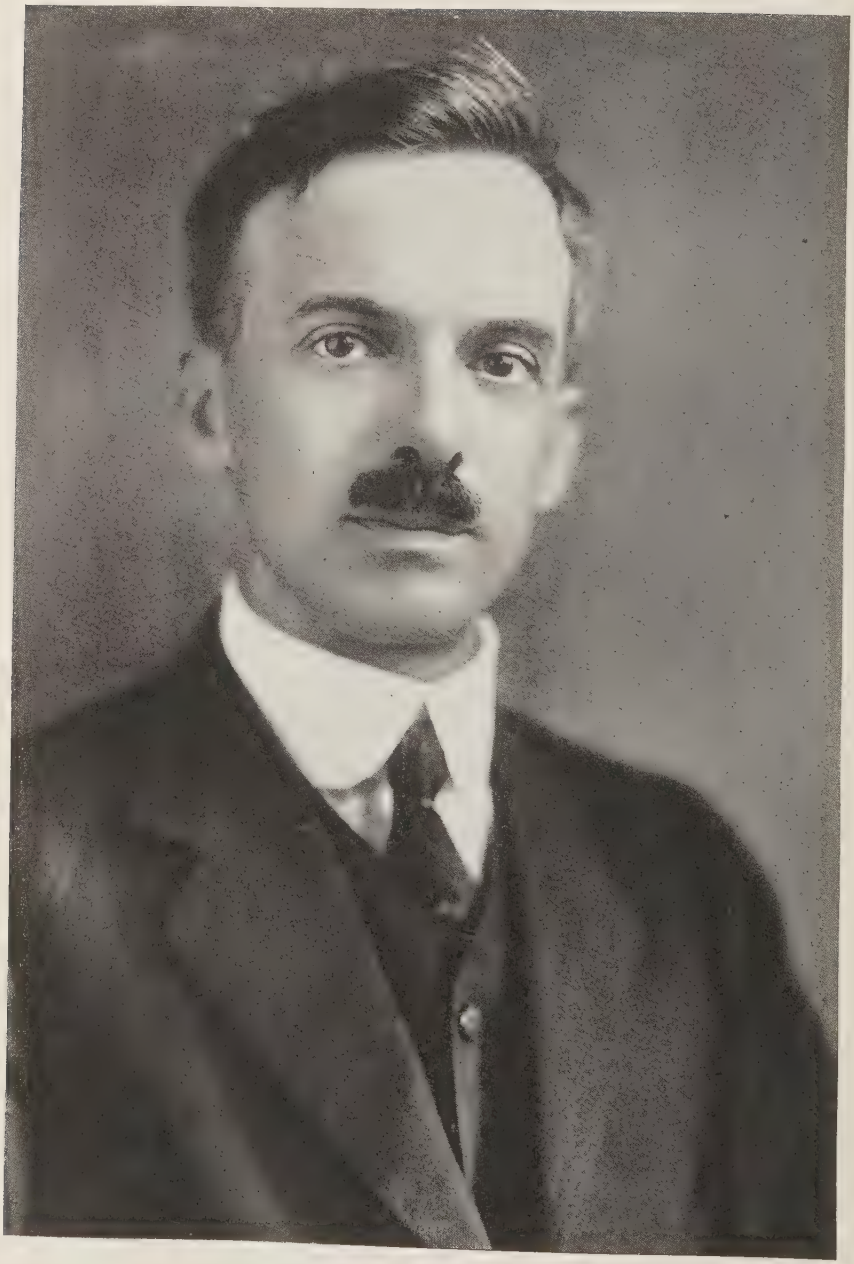
The eminence attained by Geikie in science and letters was acknowledged by the bestowal of honors from all parts of the world. Space will admit of the mention of those only that he most valued. By our own society he was awarded the Murchison and Wollaston medals, by the Royal Society a Royal medal, and from the Royal Society of Edinburgh he twice received the Macdougal-Brisbane medal. He was also the Hayden gold medallist of the Philadelphia Academy of Natural Sciences, the Livingstone gold medallist of the Royal Scottish Geographical Society, and the gold medallist of the Institution of Mining and Metallurgy. Honorary degrees were conferred on him by the Universities of Oxford, Cambridge, Dublin, Glasgow, St. Andrews, Aberdeen, Liverpool, Birmingham, Leipzig, Upsala, and Prague. He was an officer of the Legion of Honour and honorary member of a great number of the leading scientific societies at home and abroad. He was three times president of Section C of the British Association, and was president of the association in 1892. In 1910 his distinction in the world of letters was acknowledged by an invitation to take the presidential chair of the Classical Association. He was a trustee of the British Museum and a governor of Harrow School. In 1891 he was knighted, and in 1907 created a K. C. B. In 1913 he received the crowning honor of his life, the Order of Merit.

This crowded life closed peacefully on November 10, 1924. Toward the end gradually failing strength prohibited him from leaving the home that he had made at Halsemere, but his mind remained

active to the last, and it was not until a few months before his death that the busy pen was allowed to rest. From early youth until old age could no longer be denied his career had been one of uninterrupted progress. When fresh from school he attracted the attention of the most eminent geologists of the time; in the profession which he chose and in the societies which he joined he rose to the highest posts; in every country he visited he won the respect of its most eminent scientific men; every function that he attended gained in significance and dignity by his presence.

The keynote of his success was industry directed by sagacity. An innate love of writing and a remarkably retentive memory kept his pen always busy. The most arduous day's work in the field or the office put no check upon his reading and writing, and both were of the best, for he loved a good author and had himself cultivated the power of narrating the marvels which he had wrested from nature in language worthy of the theme. A clear if somewhat cold judgment controlled his actions, but in his biographical work the coldness was masked by a studied kindliness of expression. Though he made many friends at home and abroad, his sympathies with his fellow men were somewhat overshadowed by his love of nature and passion for work. He did not seek collaboration, but preferred to work single handed, nor could he brook criticism.

Archibald Geikie now takes his place in history as one who has enriched the world by his labors and his writings, and as one of those outstanding leaders who has raised the science of geology to a higher plane than that on which he found it.



NED HOLLISTER

NED HOLLISTER (1876–1924)[1]

By Wilfred H. Osgood,
Field Museum of Natural History, Chicago

[With 2 plates]

Although Ned Hollister's death occurred before his years had reached the half century mark, the consciousness that he is gone brings pangs similar to those evoked by the passing of older naturalists belonging to another generation. He was one of those heart-and-soul, born lovers of animals, who carry not only an affectionate sympathy for living things but also a passion for orderly knowledge of them—one of those whose career began in boyhood with the formation of a collection of his own and led on, without benefit of school or college, to mastery of difficult technical subjects as naturally and easily as if he had been ordained for it.

He was born November 26, 1876, in Delavan, Wis., the youngest of a family, including also two brothers, Warren D. and Kenneth, and a sister Margaret. His forbears were of English blood, one of the better known of them being Lieut. John Hollister, who came to America in 1642 and was later prominent in the colonial affairs of Connecticut. His grandfather was a native of New York State and thence, in 1839, migrated to southern Wisconsin, where he settled in Rock Prairie, Walworth County. His father, Kinner Newcomb Hollister, was born near Delavan on a farm which he continued to own after moving into town and opening a store. He sold this business to enter the Civil War, where he was commissioned captain, and after the war returned to Delavan to continue in a general merchandise business until his death in 1911. Ned's mother, Frances Margaret (Tilden) Hollister, is still living in Delavan. They belonged to that class of well-informed, prosperous, and independent people which makes nations great, engaged mainly in farming or local business connected with farming. Their home was one in which nothing essential was lacking, and while the great outdoors was always at hand, it was supplemented by the social and educational advantages of the village and by proximity to the two large cities—Chicago and Milwaukee.

[1] Reprinted by permission from Journal of Mammalogy, vol. 6, No. 1, February, 1925.

Ned's formal education was confined to the public schools of Delavan, where he had the usual high-school training but failed actually to graduate, a collecting trip having conflicted with the last few days of the school year. Although he did not go to college, early associations were made by which his natural tendencies received all that was necessary to give him an understanding of scientific method and an appreciation of absolute accuracy exceeding that of many college-trained men. One of the first of these profitable contacts was with Prof. Ludwig Kumlien, of Milton College, in the small town of Milton, Wis., not far from Delavan.

It is not uncommon for naturalists to show their inclinations early in life and they often make real contributions to knowledge while still in their teens, but few, if any, have begun earlier than Ned Hollister. In his joint work with L. Kumlien on The Birds of Wisconsin, published in 1903, it is stated that conclusions were based on 35 years' field work by the senior author and 15 by the junior. This implies that Hollister regarded his field work as beginning when he was 12 years old. If he says so, we may be quite sure it did, not theoretically but actually, and the statement in The Birds of Wisconsin undoubtedly means that at least some of the matter published in the book was founded by definite observations or notes made by the boy of 12. Further evidence is shown by the fact that he began publishing in his sixteenth year, in 1892, when three papers appeared under his name, one in The Oologist and two in a leaflet called The Taxidermist.

Early bird's-nesting and taxidermic efforts were made in the company of his brother Warren, and the collection of birds, eggs, and latterly of mammals which was brought together was a joint affair, Warren only relinquishing his interest after he had left home and entered an active life of business. Young Ned and his brother evidently were favorites among a coterie of sportsmen citizens of Delavan who took them on their semiannual shooting parties to the near-by lakes and prairies where ducks, snipes, and other game birds abounded. His father encouraged him, and an uncle, Mr. F. E. Burrows, often accompanied him to photograph birds' nests. On his father's farm near Delavan were several duck "holes" which furnished him a private preserve, and on family farms in Minnesota and Florida, he had welcome headquarters for hunting and collecting. These early hunting associations were very dear to Hollister and in later years, long after he had become immersed in scientific study and executive work in Washington, he returned to Delavan practically every season to shoot over the old ground and visit with what he affectionately and truly termed "the old crowd," for most of them were much older than he.

The life in Delavan, the early collecting, and the hunting parties with older men formed an important part of Hollister's background. Good sportsmanship, manliness, loyalty, camaraderie, judgment, and fun-loving humor were qualities which he possessed by nature, but doubtless their development was assisted by these associations. There was another and more intense side to him, however, and this also had a favorable environment. He was the heir, so to speak, of a line of pioneer naturalists in southern Wisconsin which included Lapham, Hoy, Thurè Kumlien, and Ludwig Kumlien. The last was the one to form the connection and he exerted an important influence upon Hollister when he was at the critical age of 19.

Kumlien was then teaching in Milton College and, although Hollister was not a student of the college, he "walked with" Kumlien to better purpose than many of those who were. Shortly after this, Hartley Jackson, now a well-known mammalogist but then a boy of 16 and four years younger than Ned, came to Milton College as a student and the two were brought together by Kumlien. After Kumlien's early death, Hollister became a mentor for Jackson as Kumlien had been for him, and later was instrumental in bringing Jackson to his present position with the Biological Survey. Probably through Kumlien, he became acquainted with others, including members of the Wisconsin Natural History Society, among whom were Dr. H. V. Ogden, Dr. Ernst Copeland, and Dr. G. W. Peckham, of Milwaukee. As early as 1892 he was in touch with the United States Department of Agriculture and began collecting birds' stomachs to assist the Government work in economic ornithology. It was in this year, also, that he began earnestly to collect birds' skins as well as eggs and was soon exchanging and corresponding with many prominent ornithologists. One of them was William Brewster, whose well-known warmth toward younger men soon caused Hollister to send him various specimens for determination and to ask his advice on matters concerning them. Just how Hollister would have developed without these favorable influences is uncertain, but one can not avoid wondering what would be the fate of a boy like him in present times when, with rare exceptions, there are no Kumliens in our small colleges and no Brewsters forming private collections. Even as it was, he did not find himself immediately, and for several years after reaching his majority he remained in Delavan assisting in the general store kept by his father. Meanwhile, all spare time was devoted to his collections and short trips were made at all opportunities. In 1896 and 1897 he had outings in Minnesota near the town of Kinbrae, and for three succeeding winters a few weeks were spent in Arkansas in Lonoke, Arkansas, and Prairie Counties. At this period his interest in mammals had been awakened and he made his first mammal skins

for permanent preservation in 1896. At the same time, he began compiling a list of the species of Walworth County, Wis.

In March, 1901, Ned made an eastern trip to visit the Smithsonian Institution and National Museum, places which had been enshrined in his boyhood fancies. He was always very modest and doubtless made no advances to any of the men he met in Washington, but the following summer he was invited to join a Biological Survey party in Texas as assistant to Vernon Bailey. The appointment was for temporary services only, and he gladly accepted for a period of four months, June to September, inclusive. In later years, he often related with much good humor the trepidation with which he went to meet the famous naturalist, whose name he had seen so frequently in print and whose prowess as a traveler and discoverer of new mammals had seemed to portend a man of extraordinary physique and commanding, perhaps domineering, character. Ned was by no means provincial, but in such reminiscences always represented himself to be; and it was this that gave point to his amusing description of his surprise when he found Mr. Bailey to be a man no larger than himself, quick, wiry, and active, unassuming and sympathetic. Ned's keen sense of humor was also titillated on this occasion by the fact that Bailey suggested that they have a conference in a quiet place and for this purpose chose the cemetery in the little village of Jefferson, Tex. He worked with Bailey for a time and came to have great admiration for him. Soon proving competent for independent assignments he made important collections of mammals and birds at Joaquin, Sour Lake, Comstock, Fort Stockton, and Davis Mountains, Tex., as well as at Weed, Cloudcroft, Ruidoso, Roswell, and Fort Sumner, N. Mex.

In the fall of 1902, he returned to Delavan, went for a deer hunt in Vilas County, Wis., and then, evidently intending to continue as a private collector, he bought the Kumlien collection of about 1,500 specimens and added it to his own in February, 1903. Kumlien's death in December, 1902, after a long illness, was a sad blow, and the Birds of Wisconsin, on which the two had been working for years, was left to be completed by Hollister. The winter of 1902–3, therefore, was spent largely on this work and the book appeared in July, 1903, a model of care and accuracy. Although a dozen or more notes and short articles had appeared previously, this was his first lengthy publication.

In the spring of 1903, the question of temporary field assistants again arose in the office of the Biological Survey, this time in connection with an Alaskan trip to which I had been assigned. After a word with Mr. Bailey, I quickly decided that Ned Hollister was the man I wanted and at once made a proposal to him which he accepted.

We met one evening about the first of May in a railroad station in Chicago where we immediately took train for the West. I can never forget that first evening during which we became acquainted and talked over plans for the summer. Although I had then been some five or six years on the regular staff of the Biological Survey, and although he half-jokingly and self-deprecatingly referred to me as a "professional," we were about of an age, and the rate at which we found common ground on all sorts of subjects has scarcely ever been equaled in my experience. Evidently he did not find me larger nor more muscular than anticipated and I particularly remember the droll but emphatic way in which he expressed himself as I led the way from the dining car to the comfortable smoking coach. "You're the first Biological Survey man I've seen," he said, "who didn't act as if he thought I was a criminal every time I lit a cigar."

The Alaskan trip lasted five months, joint work being done mainly in mountains near Eagle and along the Yukon River from Eagle to Circle. Hollister also did independent work on the coast at Mitkof Island and Kupreanof Island, Alaska, and at Steilacoom and San Juan Island, Wash. One of the mammals obtained at the last locality was named for him, *Peromyscus maniculatus hollisteri*. Throughout the trip, he impressed me more for all-around balanced qualities than for outstanding ones. The broad fact about him was the all-embracing character of his love of animals and nature. Down to the meanest detail of work, there was nothing connected with the observation and study of animals, alive or dead, which did not partake of this love. Each phase of the subject was to him only part of one whole, none of which was to be slighted. The excitement of the chase and the exultation of capture or discovery held great charms for him, but the laborious paring of hides and other supposed drudgery seemed to give him no less pleasure. He did such things not only with good cheer but with an obvious enjoyment that was related not to the work itself but to its object. The finished specimen was to him something to be treated almost as if sacred. I have never known a man who, without being meticulous, took such pride in the quality of his specimens and such care of them subsequent to preparation. He evinced the same joy and maintained similar high standards in method and practice in making field notes, in keeping catalogues or records, and in publishing results.

To his qualities as a collector and observer was added a charming disposition in which modesty, simplicity, loyalty, and good humor were the leading features. An amusing incident never escaped him nor ever left his memory, so no one was long in his company without being entertained by a dry comment or a humorous anecdote. As a field companion, he was delightful and his equal will very rarely be found. He loved human beings, as such, regardless of appearances

or station, and in traveling made friends among all classes with an unerring instinct for those with sound fundamental virtues. He was passionately fond of dogs and the only regret he ever expressed in connection with long field trips was that he could not take his dog. His favorite dog was a pedigreed English setter, "Chick Stanton," which he had raised from a pup and trained for hunting and field trials. During the long field season when I was intimately associated with him, nothing impressed me more than his love for this dog. When other subjects failed, he was always ready to talk about dogs, and, at times, it seemed as if he loved "Chick Stanton" more than mother, brother, or any human being. That he had a sterner side, strong convictions on many subjects, and great determination, however, was evidenced in many ways. As a good instance, a misfortune which befell him when he first began collecting mammals in Delevan may be cited. While he was skinning a slightly decomposed skunk, one of his fingers became infected and a bad case of blood poisoning set in. The whole arm was soon affected, discolored, and menacing in appearance to such an extent as to have caused panic in a man not endowed with nerve and determination. The local doctors, fearing the possible loss of his life, decided that amputation of the arm at the shoulder was the only safe course. When this information was given to the patient, he told them that his ambition to be a one-armed man was absolutely nil and that rather than permit them to operate he would take the small chance of life which they offered as the alternative.

On returning from Alaska in October, 1903, he again went to Delavan and again worked with his father in the store, but a few months later accepted another special detail from February 7 to April 10, 1904, as the representative of the Biological Survey on a hunting trip to Louisiana in company with Mr. W. E. Forbes, of Boston, and the well-known guide, B. V. Lilly. In June of the same year he was appointed to the field staff of the Biological Survey and, with the exception of a short furlough in the spring of 1906, was continuously employed in the field or in Washington until 1910. During this period he made two long field trips. The first began in Promontory, Utah, June 5, 1904, and ended at Magdalena, N. Mex., October 25, 1905. It covered some 40 localities in the States of California, Oregon, Nevada, Arizona, and Utah. The second lasted from May 6 to November 2, 1909, and was entirely in California. His collections for the Biological Survey reached a total of 3,625 mammals and 1,509 birds.

It was not until mid year in 1906, after his long trip in the West and his subsequent furlough, that he found himself in Washington, authorized to do something for the Biological Survey other than

field work. His genius in the museum was immediately recognized and he was placed in charge of the care and arrangement of the huge mammal collection brought together by the Survey. To this task he brought all the enthusiasm and devotion he had given to his own collection in Delavan. Results were soon apparent, and there was no doubt among older heads that in Ned Hollister the Biological Survey had a "find." At the age of 30, largely self-taught, and having an experience mainly of field work, he began to delve into the literature of mammalogy and to show a capacity for straight thinking on matters relating to classification and nomenclature that was surprising. It was simply a part of his great love for the entire subject and, like the rest of it, he did it thoroughly and well.

On April 15, 1908, he was married to Miss Mabel Pfrimmer, of Kentland, Ind. A house was bought in Washington and books and other personal property were moved from Delavan. After a long series of temporary appointments and furloughs, he was settled with definite prospects of being able to pursue the study of the subjects upon which his heart was set. His wife brought a fine sympathy for his work and, especially by an extensive knowledge of modern languages, was able to be of material assistance to him.

Late in 1909, Hollister accepted an offer of the position of assistant curator of mammals in the United States National Museum and took up his duties there January 3, 1910. Outwardly and aside from the slight increase in salary, the change may have appeared to some as mainly one of title, for at first it merely meant moving into a new office and working on another collection housed in the same building. But the difference was a very great one to him, for if ever there was a man who belonged in a museum and nowhere else it was Ned Hollister. From the days when the "Hollister Brothers' Museum" grew from a single cowbird's egg to the full occupancy of two rooms in the Delavan home, nothing was more evident than his passion for all phases of museum work. His first task in the National Museum was a staggering one, but he went to it single handed as blithesomely as a school boy sent to meet his father at the circus. The new building had just been completed and the mammal collection was moved to it in April, 1910. Mr. Miller, curator of the division of mammals, was absent in Europe and, therefore, Hollister found himself with the entire responsibility for moving, installing, and rearranging the great reference collection. His own report of the first stages of the work, submitted to the head curator of biology July 1, and published in the Museum's annual report, is as follows:

> After the study skins were moved to the new building, late in April, work was at once begun on a thorough and careful systematic arrangement of the entire collection, so badly needed for many years. The Primates, Carnivora,

Ungulata, Edentata, Marsupialia and Monotremata are now entirely arranged in the new cases in perfect systematic order, so that any particular specimen, or all of the specimens of a given group, can be found at a moment's notice. It is now possible to ascertain, in a short time, just what specimens the museum possesses in any genus of these groups, and what material would be desirable to build up and fill out the collection at its weak points.

How much this means can only be appreciated by those familiar with the conditions under which the collection had been kept for years in the old National Museum building where some 70,000 specimens had been crowded into space scarcely sufficient for one-fourth that number. The work so well begun was continued until all groups were covered and for the first time in the memory of anyone now living the mammal collection of the National Museum was organized and systematized as a mammal collection should be. The great series of skeletons and the very numerous skulls of large size unaccompanied by skins also were overhauled as well as the bulky and very valuable cetacean material so well represented in the collection. Nothing was slighted, but even Hollister could not stay on such a task continuously, for there was so much of interest to be done in other ways. So, with Mr. Miller's encouragement, he seized all opportunities to enter into the study of exotic mammals, a subject which was new and very attractive to him. In this way, in a few years, he familiarized himself, so far as they were represented in the Museum, with the mammal faunas of tropical America, the Philippine Islands, Celebes, China, Siberia, and eastern Africa. He published numerous papers covering a wide range of subjects and soon became recognized as one from whom sound, carefully considered contributions were to be expected.

He continued in this way for nearly seven years, only interrupted by two important field trips in 1911 and 1912. The first of these was to Jasper Park and the Mount Robson region of the Canadian Rockies, where he was in charge of the Museum party including J. H. Riley, C. D. Walcott, jr., and H. H. Blagdon, acting in cooperation with the Alpine Club of Canada which afterwards published his detailed report. The second trip also was cooperative, being made in conjunction with Dr. Theodore Lyman, of Boston, and the Museum of Comparative Zoology. The objective was the Altai Mountains of Siberia, entailing a journey to St. Petersburg and thence across Russia and Siberia. Although the entire trip lasted only four months and bad weather conditions were encountered, an important collection of mammals was made, including 13 new species and subspecies as well as many others theretofore unrepresented in any American museum.

Hollister's life, while directly connected with the National Museum, was one that appeared to satisfy him completely. So fasci-

nated was he with the nature of his work and so engrossed in each problem encountered that he was accused of neglecting his friends and failing to enjoy the social advantages with which Washington abounded. Therefore, in November, 1916, when he was invited to become superintendent of the National Zoological Park, which, like the National Museum, is a subsidiary of the Smithsonian Institution, he perhaps accepted with some misgivings. Although by his transfer the Zoo gained a very competent officer, the Museum lost one of the most gifted and devoted curators who ever sat in one of its offices.

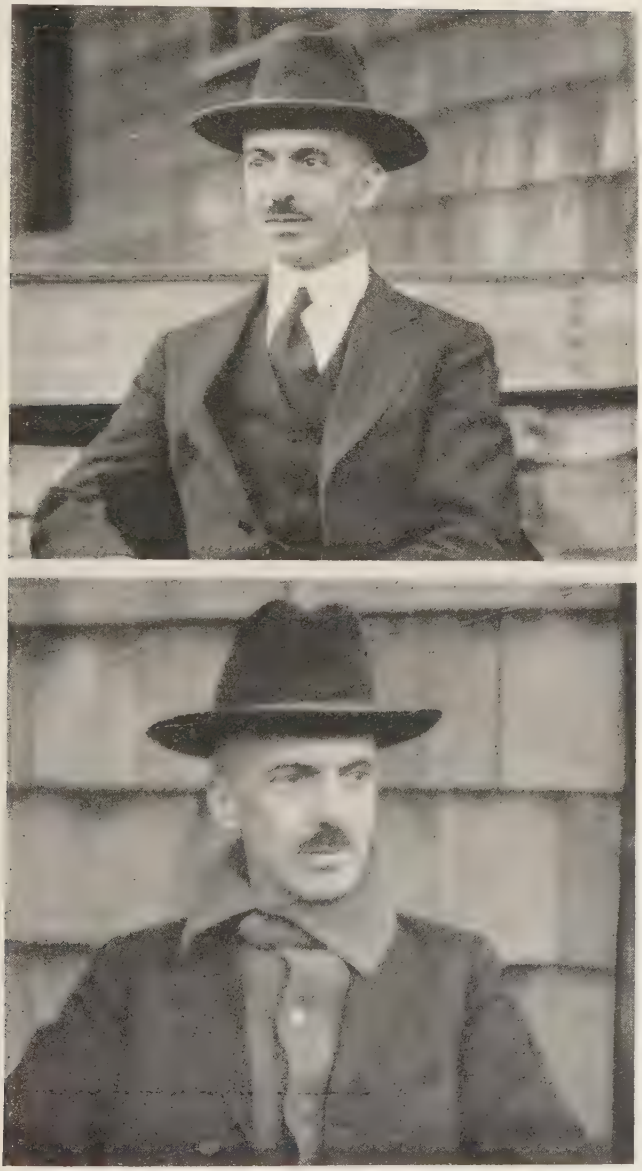
As superintendent of the National Zoological Park from November, 1916, until the date of his death, he led a somewhat different life, still in Washington, still with many of the same personal associates, and still in touch with the National Museum, but with many executive and administrative responsibilities which deprived him of coveted time for study and research. His broad knowledge of animals and his genius for order and system were brought to bear on the problems of the Zoological Park with signal success. During his administration, the collection of living animals became larger and more varied than at any previous time. The attendance increased until it reached a total of 2,400,000 visitors in 1923. The grounds and animal quarters were improved in many ways. The deer and other ruminants were given increased space, and their yards, formerly much scattered, were brought together systematically to form an orderly and instructive series. One project in which he took much personal pleasure was the forming of a special collection of American waterfowl. A small pond, previously used for miscellaneous birds, was surrounded by enlarged space and made especially suitable for this purpose. The collection grew to contain some 40 or 50 species and the conditions were so arranged that nearly one-fourth of them laid their eggs and hatched young annually. In presenting the needs of the park to Congress, Hollister was also successful in years when appropriations for such purposes were very difficult to obtain. Largely through his efforts, a valuable frontage on an important street was purchased and added to the park area, thus insuring a highly desirable approach which doubtless will be greatly appreciated in future years. In his relations with the numerous employees of the park, from gardeners, gatekeepers, and policemen to office associates, he was exceptionally sympathetic and universally popular. Besides his annual report, which was prepared and published each year, he produced a popular illustrated guide to the animals in the park which had a large sale, probably exceeding 30,000 copies.

Despite the distractions of his responsible position, Hollister still found time for research, probably in many cases by burning the mid-

night oil. His output of shorter papers continued at a somewhat reduced rate, but was still varied in character. During his last years he was occupied chiefly with a large work involving much bibliographic search and much handling of material. This was his East African Mammals in the United States National Museum, which appeared in three volumes in 1918, 1919, and 1923, respectively. It was his most important contribution to mammalogy. Ostensibly a report on the East African collections made by Theodore Roosevelt, Paul Rainey, and others, it was in reality a full résumé of the history, nomenclature, and relationships of one of the largest (probably the very largest) mammal faunas now existing. With the possible exception of his good wife, no one knows the amount of fidelity and care he devoted to this nor under what difficulties it was done.

His full bibliography appears at the end of this article. It may be said here only that it comprises well over 150 titles, important among which are: The Birds of Wisconsin (1903), A Systematic Synopsis of the Muskrats (1911), Mammals of the Philippine Islands (1911), Mammals of the Alpine Club Expedition to Mount Robson (1913), Mammals Collected by the Smithsonian-Harvard Expedition to the Altai Mountains (1913), A Systematic Account of the Grasshopper Mice (1914), and East African Mammals in the United States National Museum (1918–1919–1923). In the course of his field work, he collected the type specimens of 26 mammals, and the new mammals named by him total 162.

Mr. Hollister was a member of various scientific societies, many of which saw fit to honor him with office as well as to avail themselves of his most capable services. He was for a time an associate editor of the Journal of the Washington Academy of Sciences, having served his apprenticeship on the publication committee of the Biological Society of Washington. In 1921 the Biological Society elected him its president, and his name was thus added to a roster of presidents including most of the leading zoologists and botanists who have lived in Washington during the past half century. He was a corresponding member of the Zoological Society of London. He was one of the signers of the original call for the organization of the American Society of Mammalogists, and one of the principal participants in its actual launching. At the first meeting in April, 1919, discussion quickly focussed on whether or not Hollister would or could find the time to serve gratuitously as editor of the Journal. He would, and he could, and he did with such results as all of us have seen, in the faultlessly neat, accurate, and scholarly journal which he has produced for us for the critical period of the first five years of the society's existence. That it was no small burden to



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him there can be no doubt. At a special meeting of the directors of the society held November 20, 1924, a brief memorial resolution was adopted, and it may be ventured that no board of directors ever passed a similar resolution in which the literal sentiments expressed were more keenly felt by every member. It is as follows:

> In the death of Ned Hollister, charter member and editor of our Journal since its establishment, the American Society of Mammalogists has sustained an irreparable loss. But most of all each of us mourns the departure of a warm personal friend. We shall long miss him for his congenial companionship, his ready helpfulness, his unvarying patience, his keen intellect, his scientific skill, his sterling worth. Therefore we, representatives of the society, hereby record our deep grief in the loss of our friend and coworker, and our keen appreciation of his rare qualities as a scientist and as a man; and we extend to his bereaved widow, his mother, his brothers and sister, our heartfelt sympathy in the greater sorrow which is theirs.

No further summary of his character and achievements seems necessary. A man loved, respected, and honored has gone from a small company. It is, indeed, a very small company, for if we take stock of ourselves, we can not but realize how few are the real students of mammals. The type represented by Ned Hollister is one which, under present economic and social conditions in this country, seems threatened with extinction while yet the need for it continues to be very great. Therefore, his passing before his time is the more to be regretted. We mourn a genial friend beloved for his attractive human qualities, and we deplore the absence of a colleague of trained ability; but, when we look for his like among the coming generation, we are brought to the distressing realization that this is not all, for no one stands ready to fill the gap in the ranks.

BIBLIOGRAPHY OF NED HOLLISTER, 1892–1925[2]

Hollister's first paper, The House Sparrow in America, was published in 1892, his last, A Modern Menagerie: More about the National Zoological Park, appeared in 1925, nearly a year after his death. The total number of titles that I have been able to find is 165. Preparing this list has been made easy by the systematic and careful manner in which all of the articles up to the end of 1922 had been catalogued and bound by their author. These bound volumes, through Mrs. Hollister's kindness, are now at my disposal. Without them it would have been nearly impossible to find many of the earlier printed notes so important to an understanding of the writer's later development. In these short articles written by the boy of 16 to 20 years we already see that combination of enthusiasm and clear judgment which afterward became the main characteristic of the trained zoologist. "Floridan Races," printed in The Oologist of

[2] Prepared by Gerrit S. Miller, jr.

June 1893, before its author was 17 years old, is a good example. The later papers are noteworthy for clearness and convenience of arrangement, for the soundness of the views which they contain, and for the breadth of the field which they cover.

Up to and including the year 1908 Hollister's publications relate exclusively to birds. From 1909 onward they are chiefly devoted to mammals, with occasional returns to the field of ornithology and a single excursion into herpetology (February 17, 1913; No. 58). In the lists which follow I have first enumerated the titles chronologically, and have then arranged the 167 new names—generic, subgeneric, specific, and subspecific—alphabetically, placing after each the serial number of the article in which it was printed and the page on which it first occurs.

1892

1. **The House Sparrow in America.** *Taxidermist*, vol. 1, pp. 121–122. April, 1892.
2. **Notes from Southern Wisconsin.** *Oologist*, vol. 9, pp. 147–148. May, 1892.
3. **Wisconsin Swallows.** *Taxidermist*, vol. 1, pp. 150–152. June, 1892.

1893

4. **Floridan Races.** *Oologist*, vol. 10, pp. 176–178. June, 1893.
5. **Ducks in Southern Wisconsin.** *Ornithologist* and *Oologist*, vol. 18, pp. 128–129. September, 1893.

1894

6. **Some Winter Bird Life.** *Oologist*, vol. 11, pp. 207–209. June, 1894.

1896

7. **Notes from Southern Wisconsin.** *Wilson Bulletin*, No. 8, pp. 2–3. May 30, 1896.
8. **Evening Grosbeak in Southern Wisconsin.** *Auk*, vol. 13, pp. 259–260. July, 1896.
9. **Recent Record of the Passenger Pigeon in Southern Wisconsin.** *Auk*, vol. 13, p. 341, October, 1896.

1897

10. **Young of the Killdeer (Aegialitis vocifera).** *Wilson Bulletin*, No. 12, p. 4. January 30, 1897.
11. **Southern Wisconsin Notes.** *Wilson Bulletin*, No. 12, pp. 4–5. January 30, 1897.

1899

12. **Passenger Pigeon Note.** *Recreation*, vol. 11, p. 134. August, 1899.

1901

13. **Helminthophila pinus in Wisconsin.** *Wilson Bulletin*, No. 35, pp. 30–32. May 30, 1901.
14. **Capture of Sabines Gull in Wisconsin.** *Auk*, vol. 18, p. 392. October, 1901.

1902

15. **Notes on the Winter Birds of Arkansas.** *Wilson Bulletin*, No. 38, pp. 10–15. March, 1902.
16. **The Yellow Rail (Porzana noveboracensis) in Wisconsin.** *Auk*, vol. 19, p. 197. April, 1902.

1903

17. **The Birds of Wisconsin.** *Bull. Wisconsin Nat. Hist. Soc.*, vol. 3, pp. 1–143. January, April, and July, 1903.

1908

18. **As to Spring Shooting.** *Recreation*, vol. 27, p. 80. February, 1908.
19. **Breeding of the Acadian Owl in Newton County, Indiana.** *Auk*, vol. 25, p. 221. April, 1908.
20. **Birds of the Region about Needles, California.** *Auk*, vol. 25, pp. 455–462. October, 1908.

1909

21. **Two New Bats from the Southwestern United States.** *Proc. Biol. Soc.* Washington, vol. 22, pp. 43–44. March 10, 1909.
22. **Notes on Wisconsin Mammals.** *Bull. Wisconsin Nat. Hist. Soc.*, vol. 6, pp. 137–142. (October, 1908), April, 1909.
23. **The Last Records of Deer in Walworth County, Wisconsin.** *Bull. Wisconsin Nat. Hist. Soc.*, vol. 6, pp. 143–144. (October, 1908.) April, 1909.

1910

24. **Descriptions of Two New Muskrats.** *Proc. Biol. Soc. Washington*, vol. 23, pp. 1–2. February 2, 1910.
25. **Mammals Collected by John Jay White in British East Africa.** *Smithsonian Misc. Coll.*, vol. 56, No. 2, pp. 1–12, pls. 1–2. March 31, 1910.
26. **A Check-list of Wisconsin Mammals.** *Bull. Wisconsin Nat. Hist. Soc.*, vol. 8, pp. 21–31. (January, 1910), May 7, 1910.
27. **Notes on Some Names of Lions.** *Proc. Biol. Soc. Washington*, vol. 23, p. 123. September 2, 1910.
28. **A New Muskrat from the Great Plains.** *Proc. Biol. Soc. Washington*, vol. 23, pp. 125–126. September 2, 1910.
29. **Two New African Ratels.** *Smithsonian Misc. Coll.*, vol. 56, No. 13, pp. 1–3. October 10, 1910.

1911

30. **A New Musk-Deer from Korea.** *Proc. Biol. Soc. Washington*, vol. 24, pp. 1–2. January 28, 1911.
31. **The Generic Name of the Muskrat.** *Proc. Biol. Soc. Washington*, vol. 24, pp. 13–14. January 28, 1911.
32. **The Type Locality of Mellivora abyssinica.** *Proc. Biol. Soc. Washington*, vol. 24, p. 37. February 24, 1911.
33. **New Bird Records for Delavan, Wisconsin.** *Bull. Wisconsin Nat. Hist. Soc.*, vol. 8, pp. 187–188. (October, 1910), March 20, 1911.
34. **Remarks on the Long-tailed Shrews of the Eastern United States, with Description of a New Species.** *Proc. U. S. Nat. Mus.*, vol. 40, pp. 377–381. April 17, 1911.
35. **A Systematic Synopsis of the Muskrats.** *North Amer. Fauna*, No. 32, pp. 1–47, pls. 1–6. April 29, 1911.

36. Two New Species of Epimys from Luzon. *Proc. Biol. Soc. Washington*, vol. 24, pp. 89–90. May 15, 1911.
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